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This is an eight-volume document of which volume I is a conceptual summary which can be used as a basic reference for Navy C^3. It is a guide for developing unified global C^3 networking which will ensure command survival and flexibility in a variety of operational environments. It provides a structure for the Navy C^3 system for use in system engineering management.

The executive summary gives the main points discussed in volume 1.

Volume II is a glossary.

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Volumes ~~III~~ 3 through ~~VIII~~ 8 discuss in detail activities, methodologies, and planning considerations required for a successful implementation of the C^3 concepts and philosophies contained in volume I.

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PREFACE

This is an eight-volume document of which volume I is a conceptual summary which can be used as a basic reference for Navy C^3. It is a guide for developing unified global C^3 networking which will ensure command survival and flexibility in a variety of operational environments. It provides a structure for the Navy C^3 system for use in system engineering management.

The executive summary gives the main points discussed in volume I.

Volume II is a glossary.

Volumes III through VIII discuss in detail activities, methodologies, and planning considerations required for a successful implementation of the C^3 concepts and philosophies contained in volume I.

EXECUTIVE SUMMARY

GENERAL

This document is a contribution to the development of a Navy Command Control and Communications (C^3) Architecture. In principle the concepts discussed herein are valid outside the limits of Navy C^3 and anticipate joint service consensus to establish a unified national military C^3 network structure providing common-user service to all military subscribers. The subscribers would be assured of satisfactory service based on their needs for timeliness, quality, security, and connectivity primarily through packet switching and automated network control.

DEFINITIONS

Navy C^3 is the exercise of authority and the gathering, processing, and dissemination of all data and information to direct, support, and monitor the activities of assigned forces in the accomplishment of Navy sea control and power projection missions recently articulated by CNO.

The Navy C^3 architecture is the structured framework for effective and efficient Navy utilization of resources for the post-1985 Navy C^3.

C^3 architecture includes within its scope the analysis of the two basic Navy missions (sea control and power projection) and the environment within which these missions are performed to derive the operational concept(s), the C^3 structure,* and the resource mix and capabilities.

The scope of the Navy C^3 architecture includes all Navy uses of electronics affecting C^3 information which is the indispensable ingredient of all C^3.**

The structure of the Navy C^3 system is defined and described in terms of a network. This network is called the Navy C^3 Network (NC^3N).

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*Assurance that acceptable interface and interoperability criteria are established for electronic systems (including those named or characterized by terms such as combat direction, battle management, strategic and tactical warfare, area and point defense, weapons direction and guidance, surveillance, intelligence, EW) falls within the scope of C^3

**This includes those uses of electronics which, though not intended for C^3, might cause interference to C^3 because of location, time, or spectral output

NAVY C^3 OBJECTIVES

- To provide the National Command Authority (NCA) with means for exercising authority over Navy forces
- To enable all Navy commanders at all levels to properly exercise authority to direct assigned forces in the accomplishment of Navy missions
- To enable commanders at any level to make operational decisions based on the best and latest information available

SOME OPERATIONAL CONCEPTS DERIVING FROM NAVY MISSIONS AND C^3 OBJECTIVES

Our C^3 must provide support for offensive action to simultaneously conduct:

1. Surveillance, intelligence
2. Command control
3. Weapons launch and strike

While defensively it must strike at the enemy C^3 to:

1. Defeat his surveillance, intelligence
2. Defeat his command control
3. Defeat his weapons

Our ability to do (1) through (3) both offensively and defensively must be balanced in terms of overall cost* and mission effectiveness. The US Navy may have overcompensated in the direction of defeating weapons in recent times at the expense of balanced offensive capability as well as ability to defeat a potential enemy's surveillance and command control.

The C^3 capability must be provided with due consideration to the following operationally limiting assumptions:

1. Our policies and rules of engagement may grant or appear to grant to an enemy the choice of time and conditions of an initial attack.
2. Soviet peacetime exercises are premised on coordinated, simultaneous, worldwide surprise attack against all designated high-value targets. Thus, we must assume:

   a. Our forces will be constantly under surveillance.

   b. Our high-value targets will be constantly targeted, or can be.
3. A changing environment** requires constant reassessment.

---

*Includes the cost of providing a capability and the costs associated with expected wartime losses

**Environment includes politics, economics, threat, geography, climate (weather, etc) and mission

In developing a C^3 structure:

1. The inherent authority and responsibility of commanders both upward and downward at all levels must be carefully considered.
2. The procedures for operating the C^3 networks must be part of the C^3 system design.
3. Operational and conceptual capabilities provided by the NC^3N, such as skip echelon and delegation or presumption of authority, must be in terms of allowing a range of procedures while leaving to the commander the decision as to the application of these capabilities.

Therefore, with regard to NC^3N capabilities, the following considerations apply:

1. Although skip echelon capability may be virtually open-ended with directives conceivably going from the NCA directly to the man in the field, this does not relieve any person in the command hierarchy of his command responsibility.
2. Whether or not skip echelon directives are issued, all intervening or potentially involved command levels must have full access to the relevant information at the time it is available.
3. The local commander must have the authority to limit skip echelon connectivities to some specified minimum in cases where, for brief periods, he must reserve network capacities to ensure the effectiveness and/or survival of his forces.
4. When invoking skip echelon, the higher authority assumes the responsibility for the adequacy of procedures for ensuring accurate communications* and command integrity.
5. In order to furnish the desired capability, access to the NC^3N will be a mix of two types:
   a. Loosely structured, so that system users determine, within bounds, the access rules (ie, determine precedence). This procedure is relatively flexible but is subject to user abuse which may force net control operators to invoke more structured procedures.**
   b. Strictly structured, as for computer interactive data nets. This results in relative inflexibility but ensures that the system is controlled by the net control operator so that it cannot be disrupted by user abuse.

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*Ie, the statement "aircraft ready" must not be allowed to mean "aircraft are ready to launch from ship" to one person while meaning "aircraft are over target" to another

**Ultimately it is the commander who is both system user and system operator who, by invoking control procedures, must ensure that the highest and best use is made of the system at all times

REQUIRED NC^3N CAPABILITIES

- Operational time,* connectivity

(1) End-to-end (NCA to unit) including skip echelon capability

(2) Reconfigurable especially for survivability and integrity**

(a) Nodes with real-time capability for electronic control external to the node itself, thus making effective hierarchical control possible.

(b) Timely circuit restoral as well as fault detection and isolation by mostly automatic means with effective trend analysis.

(c) Real-time capability for optimizing traffic flow among nodes.

(d) Electronic equipments which lend themselves to common management and control techniques.

(3) Delegation or predelegation of authority***

(a) Commanders will have alternate command centers, predesignated successor(s) to command, procedures for command transition, and means of notifying remaining forces, and/or commanders that assumption of command by an alternate has occurred. The emphasis on alternate locations will be towards afloat or airborne centers with secondary consideration to shore-based centers, and on succession to command rather than on survivability of the primary commander at an alternate relocation site. Further, the system design will provide even the most senior of afloat commanders the capability to exercise authority from platforms not readily identifiable as high-value targets; specifically, the commander will have the capability to operate from CG class ships in lieu of CV classes.

(b) Critical elements of information and data usually received at shore locations from remote sensors not accessible directly by afloat commanders will be redirected to alternate commanders in the event of loss of the primary node.

(4) Presumption of authority***

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*Operational time is defined as the time delay allowable from original input of available data or information to the network to the time of the operational decision utilizing the data or information (eg, for some logistics purposes operational time can be as much as 30 days – for a missile threat it can be 5 seconds or less)

**Survivability and integrity include strict access control by resistance to: physical and electromagnetic damage, exploitation for tactical and strategic information, electronic intelligence and traffic analysis, jamming of essential strategic and tactical circuits, or intercept leading to location and targeting of high-value platforms or forces

***These capabilities are to ensure continuity of operations and assumption of command (1) in the absence of intervening command echelons, (2) by seniors not normally in the chain of command, (3) of joint forces, (4) by a non-Navy commander of Navy forces

- Responsive to war (steady state) and crisis (impulse) environments
  - (a) Responsiveness to user demands by means of automated functions.
  - (b) High circuit availability due to automatic operation of most functions.
- Ability to test, exercise the network
- Ability to recall and replay events for tactical operators in operational time
- Function in structured and interactive problem-solving environments

  The first priority of any commander is the ability to communicate with other commanders or specific platforms when necessary. The automatic manipulation of information will be the next most important priority along with ability to conduct tactical command control of forces in multithreat engagements in a hostile electronic environment.
- Transparency (network users need not be aware of the processes internal to the network)
- Naturalness (ease of use by humans)

NEED FOR EXPLICITNESS IN TRANSLATING OPERATIONAL CONCEPT INTO A C^3 SYSTEM

To achieve a real system matched to its environment requires an explicit quantitative statement of the environment in which the system must operate. To the extent that individual aspects of environment and especially their interactions are imprecisely defined, system measures of effectiveness will also be imprecise. The foundation of a C^3 architecture must therefore be a strategic concept along with policy and planning guidance which addresses the environmental considerations. For example, a discussion of the Navy sea control mission must quantitatively address the geographic, climatic, and threat conditions if it is to be concrete enough to drive a command concept and a C^3 system.

In this document, many explicit (and undoubtedly many implicit) assumptions are made concerning these issues. Among the more important assumptions are some political/economic ones which have implicitly driven C^3 requirements:

1. Sea control is the mission on which any other mission depends.
2. US Navy dominance in the North Atlantic and North Pacific is indispensable to sea control.
3. The US Navy cannot ensure dominance in the Mediterranean but must ensure strategic deterrence (both nuclear and nonnuclear).

SUMMARY OF [illegible]

Because of resource constraints, under the best of circumstances it will take long-term planning and development before the C^3 objectives can be met.

First, managerial initiatives are required to incorporate available technology into new systems; second, there is a need for new technology to meet the C^3 objectives.

If Navy C^3 objectives are to be met, a unifying concept and focus must be developed leading to an agreed-on overall C^3 framework resulting in:

- Closely interrelated development, scheduling, funding, and sponsorship of electronic systems
- Attention to optimized standard interface development
- C^3 network flexibility, adaptability, and survivability. Independent dedicated links which stand or fall on their own are undesirable. Capability for mutually supporting networking and common-user alternate routing is required.
- End-to-end support to satisfy operational time constraints
- Economical use of resources and avoidance of inappropriately suboptimized systems
- The evolution and maintenance of an institutional memory
- High level of idea transfer and low level of information loss

C^3 SYSTEM CONCEPT

In developing the C^3 system concept, the document addresses structural problems related to guidance for system engineering. In particular, the difference between what a system <u>does</u> and what it <u>is</u> has been highlighted. Both aspects are required in system definition and description. In defining what a system is, classical system engineering requires specification of a system or subsystem in terms of real, tangible (not abstract) boundaries and interfaces (ie. what exactly is the engineer to construct?).*

*Currently, because of a lack of an accepted overall structured concept, there is a tendency to "solve" each isolated C^3 problem by naming a "system" which will be developed, with only a vague notion of what the physical characteristics and interfaces with other systems are to be. This results in a tendency to advertise solutions which are at best suboptimum and often only imaginary

A further constraint imposed by this document is that real subsystems must consist of mutually exclusive sets of objects so that, when the top-level system manager begins to partition the C^3 system, he can ensure a logical, nonoverlapping division of labor and specialization without the need for excessive coordination among different design organi ions. We assert that such excessive need for coordination (because of ill defined and ove lapping definitions of the physical boundaries of systems which must operate in concert) is currently unnecessarily sapping much of the energy of development organizations within the Navy.

Network theory and cybernetic theory have made considerable advances recently, a a basic conclusion is that a wide variety of large-scale problems can be represented by a hie archy of networks which can be decomposed into subhie This basic concept is introduced and structured herein for future C^3 system d generically invariant structure for treating system functions and system components (or subsystems) at any level in the hierarchy is ribed.

...NCIPAL C^3 NETWORK DESIGN FEATURES REQUIRED

The features which should be designed into the future Navy C^3 network and on which early policy decisions are required are listed below. These features must be provided in the development sequence listed because each item is technologically dependent on the prior items.

1. Central kernel on every platform: time, frequency, location, motion vector, crypto, unique address. (To ensure the necessary self-knowledge to allow participation in highly dynamic operational situations.)
2. Clock start crypto, all bits covered throughout NC^3N, including weapons guidance and surveillance networks. (To ensure that the enemy cannot characterize or ta control of network by mimicking control signals.)
3. Joint service standard adaptable rf signal formats. (To allow interoperability and to combat SIGINT.)
4. Multimedia connectivity (for P = 0.99 of successful message delivery because no single path is expected to be 99% available under hostile conditions.)
5. Automated dedicated orderwire capacity for every node. (To ensure that all nodes are assigned a minimum capacity for requesting additional network capacity when needed.)
6. Synchronous DAMA* operation of high-duty-cycle nets governed by priority. (To ensure that critical messages are delivered and that nets operate at high efficiency during crisis.)

*DAMA = Demand Assigned, Multiple Access

7. "Front-end"* processing to provide common network transaction formats, access procedures, error control, and switching for global interoperability of US forces.
8. NAVCOMMSTAs turned over to DCS as part of an integrated shore-based military communications network which is not dependent on foreign bases for essential global connectivity. (To ensure survivability and flexibility through planned redundancy at lower cost.)
9. Distributed processing nets which provide a balance of data processing and transmission workload throughout the C^3 system.
10. Microprocessor, microcomputer, smart-terminal architecture. (To provide the needed increase in processing power for minimizing transmission link data loads. This will allow more opportunity for improving other network attributes such as survivability and flexibility at reasonable cost.)

SPECIFIC SYSTEM DESIGN REQUIREMENTS

Postulated US Navy data and information transfer services required for ships and aircraft at sea to perform Navy missions are given in section 6.3. These required data and information transfer services provide (along with descriptions of the system framework, networking principles and features, threat, and system constraints (sections 6.1, 6.2, 6.4, 6.5)) the basis for proposed specific user network architectures described in section 6.6.

In addition to data and information transfer within the NC^3N, there is a requirement to specify kinds, location, and volume of input and output of the network.

Inputs are:

Data derived by radar, sonar, ESM techniques, and human observation

Information and data via links to non-Navy networks

Undesired jamming and spoofing by an enemy

Undesired natural and man-made noise or interference

Outputs are:

Desired data and information via links to non-Navy networks

Vulnerability to enemy intercept

---

*Interface processing close to data sources or user terminals to allow different types to operate compatibly on a common network. In the long run, standard interface and netting specifications would result in standard sources and terminals.

Interference to non-Navy networks

Desired outputs to allow exploitation of enemy networks by using knowledge of signal formats and network protocols to jam or spoof. (A major requirement of the NC^3N is to be able to interface with the enemy C^3 network to the extent of inducing desired uncertainty and error in his decision process.)

The specifics of these NC^3N input and output requirements are beyond the current scope of this C^3 effort. Some general principles are worth noting, however:

1. A distributed-network, smart-terminal architecture must provide for the reduction of data and processing it into information to be done as close to the input to the network as possible. This is to minimize the cost of transporting and managing large volumes of data in the network.
2. The process of gathering information by active means and transferring it makes the individual platforms vulnerable to attack. Therefore, platforms having high economic value should not be subjected to performing unique C^3 functions which will result in SIGINT being able to single them out as being of high value.
3. Electromagnetic emissions from one platform should not expose friendly platforms to detection by bistatic detection techniques.
4. The enemy will concentrate counterattacks on the platforms which attack his surveillance and C^3 capability. Therefore, these platforms should be low cost and difficult to attack. High-value units should be provided with jammers and spoofing capability only for last-ditch self-defense.
5. The major mobile command centers will typically be located on high-economic-value platforms (the large ones) and they will be disseminating a large volume of information. To prevent an enemy from using SIGINT to identify which are the command centers, the network must have a reasonably balanced signal flow and standardized signal formats. What this implies is that the smaller platforms will appear to be as active as the larger ones. Such a balance can be achieved naturally in a distributed network in that the command centers, although they are handling a lot of information, are not transmitting a lot of data; and while the smaller platforms are transmitting little information, the data rate is high because the data reduction and information correlation process is incomplete. In other words, signal balance in the network is achieved by a proper and natural balance of signal processing capability so that the more information going out of a node, the more prior information processing has been applied to each information set to reduce the data rate.

MANAGEMENT ISSUES

Various sections of this document describe or define:

How requirements should be stated

How the C^3 system should be broken into its components

The essential structure and principles and design features of the Navy C^3 architecture

A logical progression from mission and environmental analysis through C^3 system design and validation

Needed C^3 management initiatives (section 5) and R&D initiatives (section 8)

The most urgently needed C^3 initiatives (defined in section 5) are managerial ones, the lack of which delays fruition of technological solutions. Some of the needed initiatives relate to changes of managerial structures, to correct deficiencies of the kind which prompted the CIACT* (report to CNO July 1972) to admonish the Navy to organize properly.

The way funding is categorized is symptomatic of some of the structural problems. For example, the existing funding and management structure inappropriately divides C^3 into communications and command control components. (A better way of partitioning C^3 is given in this document.)**

The current science and technology objectives (S & TOs) and operational requirements (ORs) for C^3 reflect a lack of appreciation of the difference between funding line items (inputs) and mission capabilities and assume a very simple relationship between them. User needs (desired mission capabilities) are usually matched independently one to one with fund allocations. It would be better to have a combined statement of all user needs and to partition the funds to correlate with subsystems. The subsystems would be identified in the system engineering process of partitioning a common-user system aimed at satisfying the integrated set of all user needs. The outline of such a structured system design is given in section 7 and developments for achieving such a system are outlined in section 8.

*CNO Industrial Advisory Committee on Telecommunications

**In the civilian market place this division is making itself felt in terms of a major legal upheaval to try to define where regulated communications systems end and ADP systems begin.

Another major issue is that of managerial innovation. Experience has shown that organizations responsible for the current and near-term functioning of an organization cannot also be responsible for innovative thinking, since the urgent always suppresses the important. There is a continuing need for the Navy to set aside a very small amount of resources to support in-house, long-term, challenging, and innovative planning for the Navy C^3 future. Such an innovative group must be protected from the need to respond to near-term fire drills which, through their demand for manpower, will cause the group to lose its integrity and focus through growth of staff and need for constant short-view compromises.

The Navy has recognized that its ability to carry out its mission is inseparable from an integrated and comprehensive C^3 concept and system. This means the Navy must avoid fragmented management authority and organizational biases which create an environment of compromise before the fact.

There is a need to define desired C^3 capability independently of ongoing programs and prior to the design of new C^3 systems. Further, components of the C^3 system must be broken out according to a commonly accepted structure. Developments which require parallel effort in two or more components must be managed in concert. This means balanced development effort within the context of a comprehensive OPNAV architecture and NAVMAT development plan.

The Navy has taken an innovative and forward-looking point of view, in terms of planning, out to the year 2000 and beyond, about its future in naval platforms and has instituted long-term developments while sacrificing current capability (at some recognized risk) by retiring obsolete platforms.

The capabilities proposed for C^3 in this document will require developments which because of fiscal and technological constraints may take until the year 2000 to implement completely in the Fleet. This will require perseverance in maintaining the long-term view of an innovative C^3 development running in parallel with the evaluation of advanced platform concepts.

CONCLUSION

This is an eight-volume document, of which volume I is a conceptual summary, which can be used as a basic reference for Navy C^3. It is a guide for developing unified global C^3 netting which will ensure command survival and flexibility in a variety of operational environments. It provides a structure for the Navy C^3 system for use in system engineering management.

1.0 INTRODUCTION

1.1 Objective

The objective of this document is to introduce a broad general framework for the total Navy command control and communications (C^3) network architecture, and to relate Navy electronics to this framework. The document is intended primarily to support the C^3 architect and to provide inputs to the Navy C^3 architecture. Secondarily, it is intended to provide broad and general concepts for use by Navy electronic system engineers in the creation of a C^3 system development plan or any portion thereof.

1.2 Definitions and Scope

Navy C^3 is the exercise of authority, and the gathering, processing, and dissemination of all data and information to direct, support, and monitor the activities of assigned forces in the accomplishment of Navy sea control and power projection missions recently defined by CNO.

The Navy C^3 architecture is the structured framework for effective and efficient Navy utilization of resources for the post-1985 Navy C^3.

C^3 architecture includes within its scope the analysis of the two primary Navy missions and the environments within which these missions are performed to derive the operational concept(s), the C^3 structure,* and the resource mix and capabilities.

The scope of the Navy C^3 architecture includes all Navy uses of electronics affecting C^3 information, which is the indispensable ingredient of all C^3.**

The structure of the Navy C^3 system is defined and described in terms of a network. This network is called the Navy C^3 Network (NC^3N).

1.3 The Purpose of a C^3 Architecture

The purpose of the Navy C^3 architecture is to present the framework for a post-1985 C^3 system. This framework is the vehicle by which the Chief of Naval Operations provides guidance for planning, programming, budgeting, and implementing the Navy C^3 system components and to structure and support a cohesive program that is in balance with all other major warfare mission programs.

A simplified representation of the Navy portion of this process is given in figure 1-1.

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*Insurance that acceptable interface and interoperability criteria are established for electronic systems (including those named or characterized by terms such as combat direction, battle management, strategic and tactical warfare, area and point defense, weapons direction and guidance, surveillance, intelligence, EW) falls within the scope of C^3

**This includes those uses of electronics which, though not intended for C^3, might cause interference to C^3 because of location, time, or spectral output

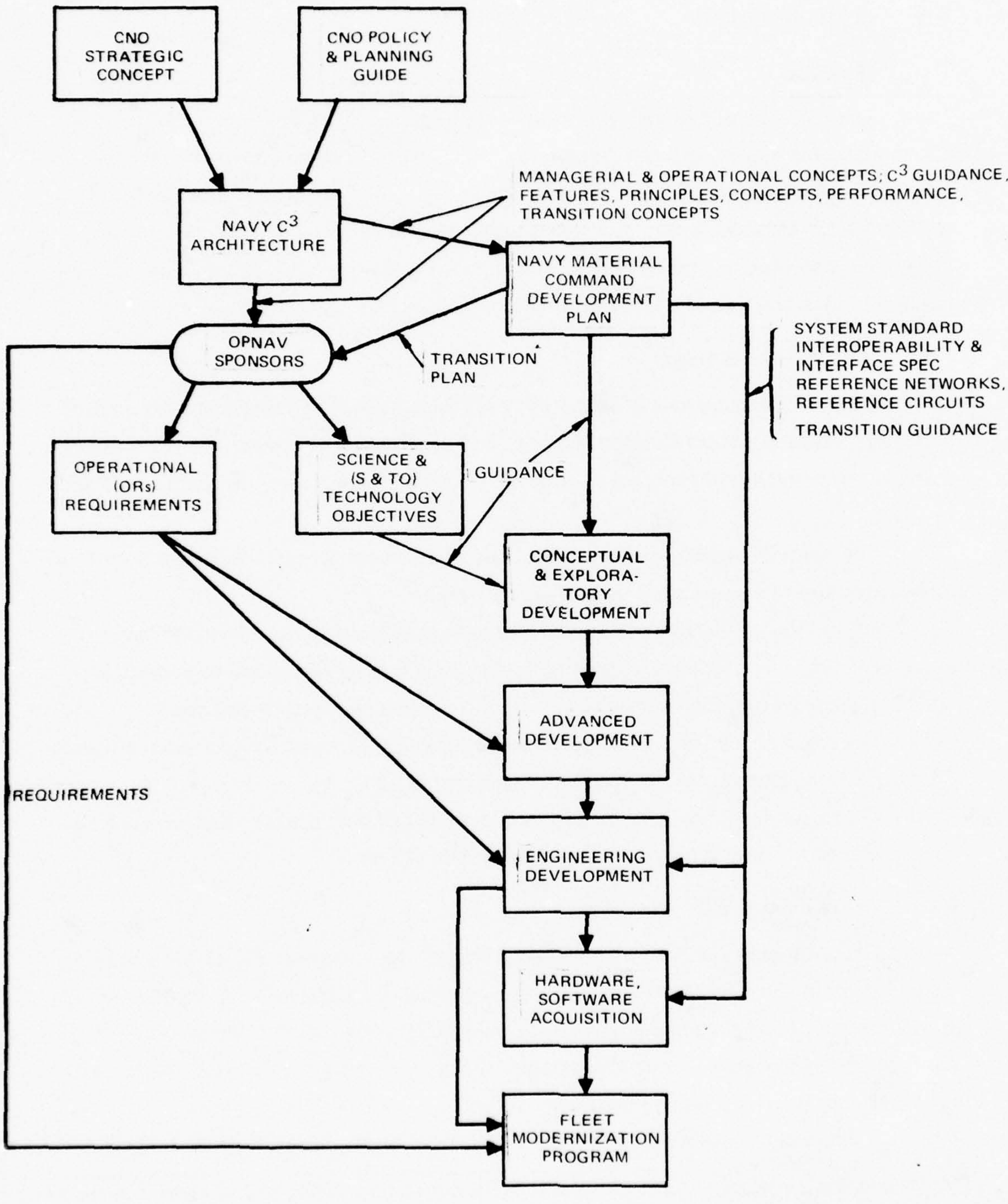


Figure 1-1. Acquisition process overview.

1.4 Glossary

Many of the words used in discussing the concepts in this document do not have a widely accepted precise meaning. An attempt has therefore been made in the discussions that follow to clarify meanings and implications of language and terms utilized. Appendix A contains a glossary of terms. Although some of the terms covered were not used in this document, these were included in the glossary as possible aids to future discussions of the document.

2.0 NAVY C^3 OBJECTIVES

- To provide the National Command Authority (NCA) with means for exercising authority over Navy forces
- To enable all Navy commanders at all levels to properly exercise authority to direct assigned forces in the accomplishment of Navy missions
- To enable commanders at any level to make strategic, tactical, and operational decisions based on the best and latest information available

3.0 APPROACH FOR DEFINING THE NAVY C^3 ARCHITECTURE

Table 3-1 outlines the approach for developing a C^3 architecture. The approach consists of analyzing and describing the Navy missions (operational concept) so that a command control structure can be defined. Then the required force mix and NC^3N capabilities are derived in sufficient detail to guide system solutions. The proposed solutions are defined in broad terms for specific network types and specific naval platform types, and finally the proposed solutions are tested with simulation models to ascertain their reasonableness in terms of cost and effectiveness. Military scenarios are used as tools for this evaluation.

Figure 3-1 shows a logical flow diagram for the approach to C^3 architecture. The numbers alongside each block indicate the sections of this document in which that block is addressed. Figure 3-2 shows the relationship between operational capability definition and system technical criteria. Operational capability is defined in terms such as need to locate and/or identify objects. Technical criteria are defined in terms of functions such as transmission and reception, information processing, and man/machine coupling.

TABLE 3-1. C^3 APPROACH

ANALYZE MISSIONS
Sea Control
Dominance in North Atlantic, North Pacific
Nonnuclear strategic deterrence in Mediterranean
Contingent sea control in other areas
Projection of Power
Nuclear deterrence
Projection of forces
Presence
DEFINE CONCEPTUAL STRUCTURE OF C^3
Combat Direction, C^3 Team Organization & Forces
Guiding Principles and Assumptions
Network Architecture
Generic Functional Description of Nodes
Generic Hardware, Software Architecture
DEFINE REQUIREMENTS FOR INFORMATION INPUT, TRANSFER, AND OUTPUT
Force/Group Requirements
Platform Requirements
Intraplatform Requirements
SYSTEM SOLUTIONS
Specific Network Architecture
Specific Node Functional Description
Specific Node Hardware, Software Architecture
ECONOMIC AND PERFORMANCE ANALYSIS
Network and Node Performance
Cost
War Gaming/Effectiveness Models

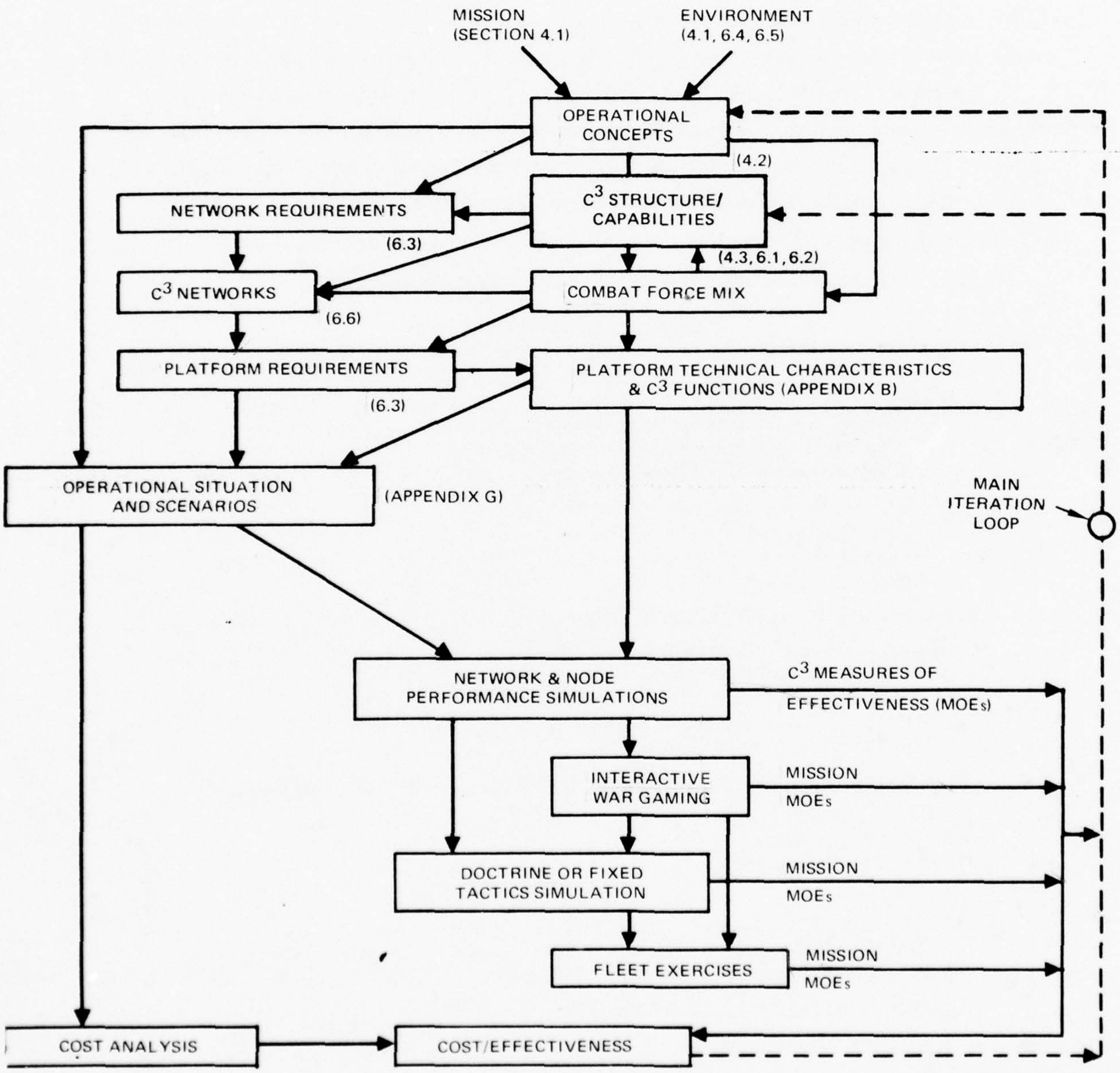
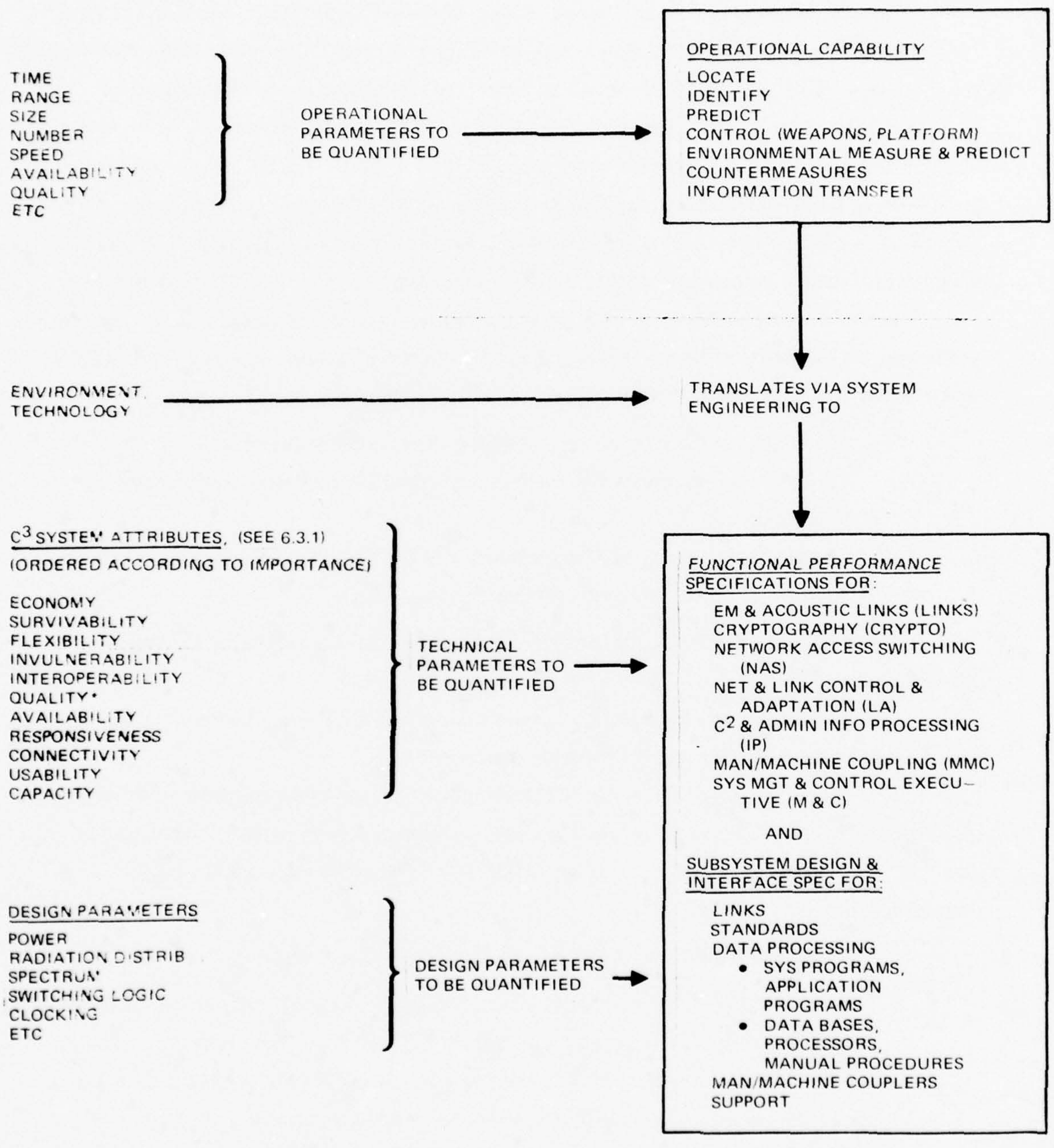


Figure 3-1. Flow diagram of C^3 architecture development.



*Quality as used here is a measure of accuracy, fidelity

Figure 3-2. Categories and parameters for defining operational capability and technical criteria for C^3 nodes and facilities.

4.0 SUMMARY OF THE OPERATIONAL CONCEPTS

4.1 Navy Missions and The Operating Environment

To achieve a real system matched to its environment requires a precise statement of the environment (politics, economics, threat, geography/climate, mission) in which the system must operate. To the extent that individual aspects of environment and especially their interactions are imprecisely defined, system measures of effectiveness will also be imprecise. The foundation of a C^3 architecture must therefore be a strategic concept along with policy and planning guidance which address the environmental considerations. For example, a discussion of the Navy sea control mission must address the geographic, climatic, and threat conditions if it is to be concrete enough to drive a command concept and a C^3 architecture.

In this document, a variety of explicit (and undoubtedly many implicit) assumptions are made concerning these issues. Among the more important assumptions are some political and economic ones which have implicitly driven C^3 requirements.

a. Sea control is the mission on which any other mission depends.

b. US Navy dominance in the North Atlantic and North Pacific is indispensable to sea control.

c. The US Navy cannot rely on dominance in the Mediterranean but must ensure strategic deterrence (both nuclear and nonnuclear).

These assumptions also drive the tactical scenarios used for validating C^3 requirements and concepts.

There are two Navy missions as was shown in table 3-1. The sea control mission was broken into three categories called "focusing concerns."

This allows the mission analysis and development of operation concepts to focus on practical and realistic factors of the environment – physical, technological, natural, and political. For example, in the North Atlantic the environmental conditions driving the operational concepts include:

- The high level and type of threat emanating from the Murmansk, Leningrad area
- The climate, the weather, and the natural and political geography affecting such considerations as choke points; ranges from US and allied shore bases to intercept points in the North Atlantic; depths to which submarines can dive (which in turn affect availability of communications service); radio communication ranges, affected by propagation conditions in that area; ice conditions; location of maritime trade routes; etc

Once the individual missions and focusing concerns are analyzed, an operational concept on a global level and individual area level must be defined so that a global C^3 structure and force mix can be defined which recognizes practical economic and political reality and determines its value.

Thus, the C^3 architecture focuses on practical considerations of environment and value so that it can drive requirements and system solutions in a way that makes maximum use of available technology. The basic concept is illustrated by figure 4-1.

The CNO Policy and Planning Guidance (PPG) FY78-82 provides the description of operational concepts to which this document is directed. Five scenarios are given in the PPG, which discusses the Navy capabilities for sea control and power projection.

The force levels are also given and the basic environmental factors which impact on C^3 are discussed in the PPG.

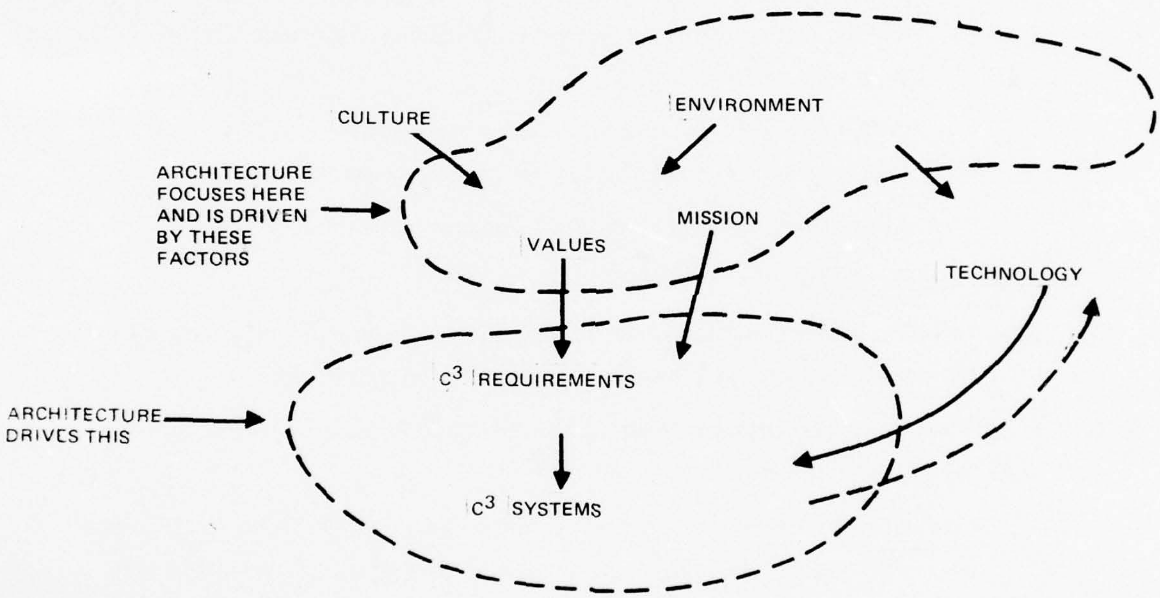


Figure 4-1. The focus of the C^3 architecture.

4.2 Some Operational Concepts Deriving From Navy Missions and C^3 Objectives

a. Our C^3 must provide support for offensive action to simultaneously conduct:

Surveillance, intelligence

Command control

Weapons launch and strike

While defensively it must provide an interface into the enemy C^3 to:

Defeat his surveillance, intelligence

Defeat his command control

Defeat his weapons

Our ability to accomplish these objectives both offensively and defensively must be balanced in terms of overall cost and mission effectiveness. The US Navy may have overcompensated in the direction of defeating weapons in recent times at the expense of balanced offensive capability as well as ability to defeat a potential enemy's surveillance and command control.

b. The C^3 capability must be provided with due consideration to the following operationally limiting assumptions:

- Our policies and rules of engagement may grant or appear to grant to an enemy the choice of time and conditions of an initial attack.
- Soviet peacetime exercises are premised on coordinated, simultaneous worldwide surprise attack against all designated high-value targets; thus, we must assume:

  Our forces will be constantly under surveillance

  Our high-value targets will be, or can be, constantly targeted
- A changing environment requires constant reassessment.

c. In developing a C^3 structure:

- The inherent authority and responsibility of commanders both upward and downward at all levels must be carefully considered.
- The procedures for operating the C^3 networks must be part of the C^3 system design.
- Operational and conceptual capabilities provided by the NC^3N, such as skip echelon, and delegation or presumption of authority must be in terms of allowing a range of procedures while leaving to the commander the decision as to the application of these capabilities.

d. Therefore with regard to the NC^3N capabilities listed in section 2.1 the following considerations are assumed to apply:

- Although skip echelon capability may be virtually open-ended with directives conceivably going from the NCA directly to the man in the field, this does not relieve any person in the command hierarchy of his command responsibility.
- Whether or not skip echelon directives are issued, all intervening or potentially involved command levels must have full access to the relevant information at the time it is available.

- A local commander must have authority to limit skip echelon connectivities to some specified minimum in cases in which, for brief periods, he must reserve network capacities to ensure the effectiveness and/or survival of his forces.
- When invoking skip echelon, the higher authority assumes the responsibility for the adequacy of procedures for ensuring accurate communications* and command integrity.
- In order to furnish the desired capability, access to the NC^3N will be a mix of two types:

  Loosely structured so that system users determine, within bounds, the access rules (ie, determine precedence). This procedure is relatively flexible but is subject to user abuse which may force net control operators to invoke more structured procedures.**

  Strictly structured such as for computer interactive data nets. This results in relative inflexibility but ensures that the system is controlled by the net control operator so that it cannot be disrupted by user abuse.

---

*Ie, the statement "aircraft ready" must not be allowed to mean "aircraft are ready to launch from ship" to one person while meaning "aircraft are over target" to another

**Ultimately it is the commander who is both system user and system operator who, by invoking control procedures, must ensure that the highest and best use is made of the system at all times

4.3 REQUIRED NC^{3}N CAPABILITIES

- Operational time,* connectivity

(1) End-to-end (NCA to unit) including skip echelon capability

(2) Reconfigurable especially for survivability and integrity**

(a) Nodes with real-time capability for electronic control external to the node itself, thus making effective hierarchical control possible.

(b) Timely circuit restoral as well as fault detection and isolation by mostly automatic means with effective trend analysis.

(c) Real-time capability for optimizing traffic flow among nodes.

(d) Electronic equipments which lend themselves to common management and control techniques.

(3) Delegation or predelegation of authority***

(a) Commanders will have alternate command centers, predesignated successor(s) to command, procedures for command transition, and means of notifying remaining forces, and/or commanders that assumption of command by an alternate has occurred. The emphasis on alternate locations will be towards afloat or airborne centers with secondary consideration to shore-based centers, and on succession to command rather than on survivability of the primary commander at an alternate relocation site. Further, the system design will provide even the most senior of afloat commanders the capability to exercise authority from platforms not readily identifiable as high-value targets; specifically, the commander will have the capability to operate from CG class ships in lieu of CV classes.

(b) Critical elements of information and data usually received at shore locations from remote sensors not accessible directly by afloat commanders will be redirected to alternate commanders in the event of loss of the primary node.

(4) Presumption of authority***

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*Operational time is defined as the time delay allowable from original input of available data or information to the network to the time of the operational decision utilizing the data or information (eg. for some logistics purposes operational time can be as much as 30 days – for a missile threat it can be 5 seconds or less)

**Survivability and integrity include strict access control by resistance to: physical and electromagnetic damage, exploitation for tactical and strategic information, electronic intelligence and traffic analysis, jamming of essential strategic and tactical circuits, or intercept leading to location and targeting of high-value platforms or forces

***These capabilities are to ensure continuity of operations and assumption of command (1) in the absence of intervening command echelons, (2) by seniors not normally in the chain of command, (3) of joint forces, (4) by a non-Navy commander of Navy forces

- Responsive to war (steady state) and crisis (impulse) environments

  (a) Responsiveness to user demands by means of automated functions.

  (b) High circuit availability due to automatic operation of most functions.
- Ability to test, exercise the network
- Ability to recall and replay events for tactical operators in operational time
- Function in structured and interactive problem-solving environments

  The first priority of any commander is the ability to communicate with other commanders or specific platforms when necessary. The automatic manipulation of information will be the next most important priority along with ability to conduct tactical command control of forces in multithreat engagements in a hostile electronic environment.
- Transparency (network users need not be aware of the processes internal to the network)
- Naturalness (ease of use by humans)

5.0 SUMMARY OF NEEDED C^3 INITIATIVES

Because of resource constraints, under the best of circumstances it may take until the year 2000 before the objectives cited in section 2.0 can be met. Further, these objectives cannot be satisfied by current development programs.

First, managerial initiatives are required to incorporate available technology into new systems; second, there is a need for new technology to meet the C^3 objectives.

If Navy C^3 objectives are to be met, a unifying concept and focus must be developed leading to an agreed-on overall C^3 framework resulting in:

- Closely interrelated development, scheduling, funding, and sponsorship of electronic systems
- Attention to optimized, standard interface development
- C^3 network flexibility, adaptability, and survivability. (Independent dedicated links which stand or fall on their own are undesirable.) (Capability for mutually supporting networking and common-user alternate routing is needed.)
- End-to-end support to satisfy operational time constraints
- Economical use of resources and avoidance of inappropriately suboptimized systems
- The evolution and maintenance of an institutional memory
- High level of idea transfer and low level of information loss and inertia

6.0 OVERVIEW OF THE NC^{3}N ARCHITECTURE

This section outlines a framework for developing a C^3 system which will satisfy Navy objectives. This logical framework is the basis for deriving the required R&D initiatives which will be outlined in section 8.0 and for resolving managerial issues which will be discussed in section 9.0.

6.1 The Framework

The NC^{3}N is a component of the globally extended national military C^3 network which is a component of a C^3 system as illustrated by figure 6-1 (ie, the network is only one of several components of a C^3 system as seen in fig 6-1). This section gives a brief overview of the NC^{3}N.

NAVY C^3 SYSTEM

C^3 MANAGEMENT	C^3 ENGINEERING	C^3 LOGISTICS	NATIONAL NC^{3}N	ETC

Figure 6-1. C^3 system functional breakdown.

The NC^{3}N includes a hierarchy of Command Control nodes and controlled nodes* as illustrated by figure 6-2.**

The NC^{3}N incorporates all these nodes tied together by links in a network. In addressing the network hierarchy and taking any level in the hierarchy, that level can be treated in terms of nodes and internodal connectivities. At that level in the hierarchy, the nodes are defined in terms of input/output specifications. The nodes can be described in terms of the network contained within them to as many lower hierarchical levels as desired (ref 1).

The NC^{3}N is the physical implementation of the global data/information gathering, processing, and distributing process which ties all systems together (including sensor and surveillance nodes and networks***) in support of Navy command control. This network is broken down into media and node elements as illustrated in figures 6-3, 6-4, and 6-5.

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*C^2 nodes are manned nodes and controlled nodes are unmanned nodes such as missiles and RPV.

**Figure 6-2 is of course an oversimplification which does not illustrate the high degree of network interlacing and skip echelon connectivity which is actually desired. This illustration is provided for the purpose of showing the concept and the invariance of the methodology for treating any level in the hierarchy

***Ie, networks of sensors in which multiple sensors, both active and passive, are used in a time and frequency ordered multinode manner (eg, bistatic detection and ranging techniques)

Ref 1. For a discussion of the relationship between information theory and hierarchical systems, see: Conant, RC, Laws of Information Which Govern Systems, *IEEE Transactions on Systems, Man, and Cybernetics*, vol SMC-6, no 4, p 240-255, April 1976

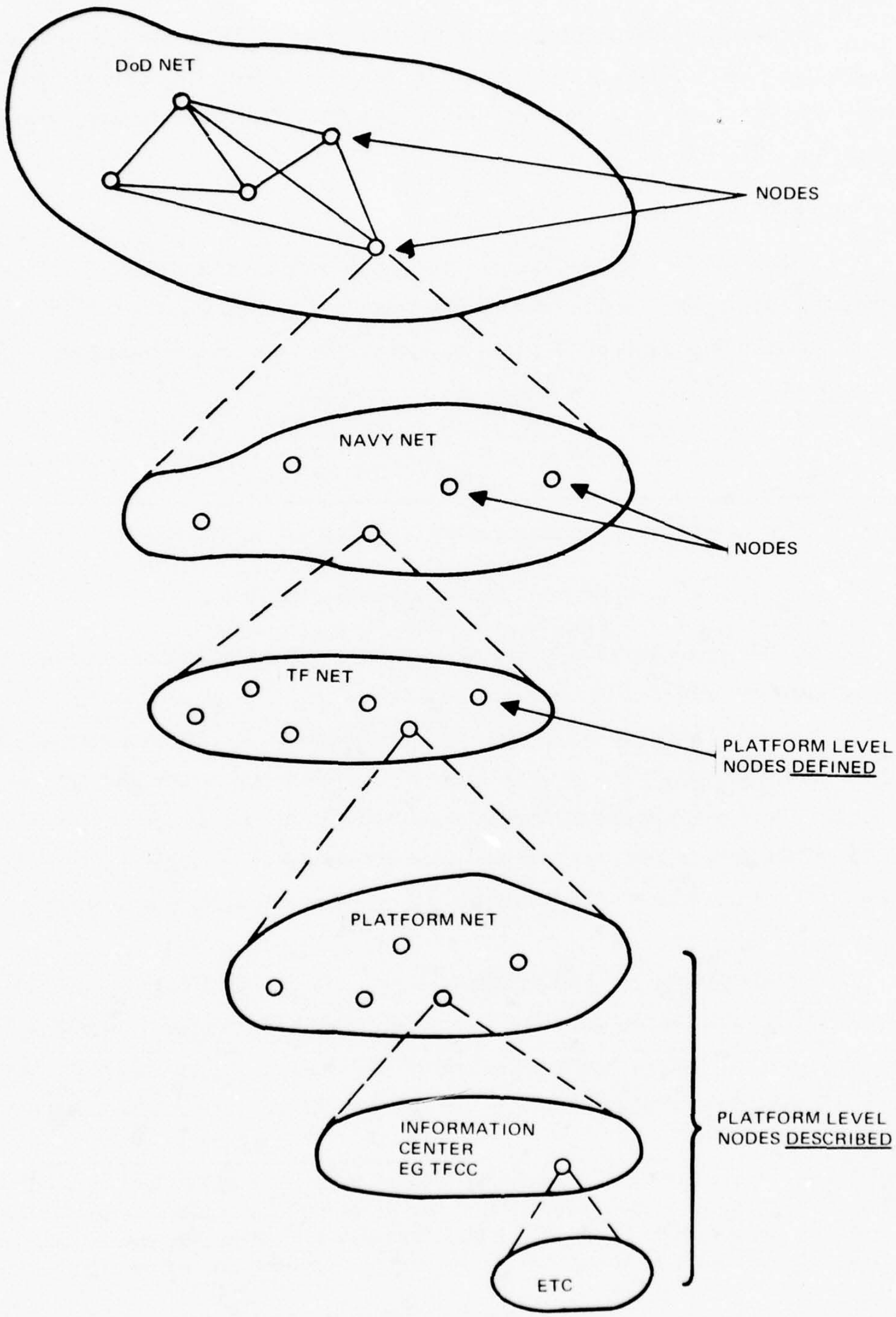

Figure 6-2. Network hierarchy.

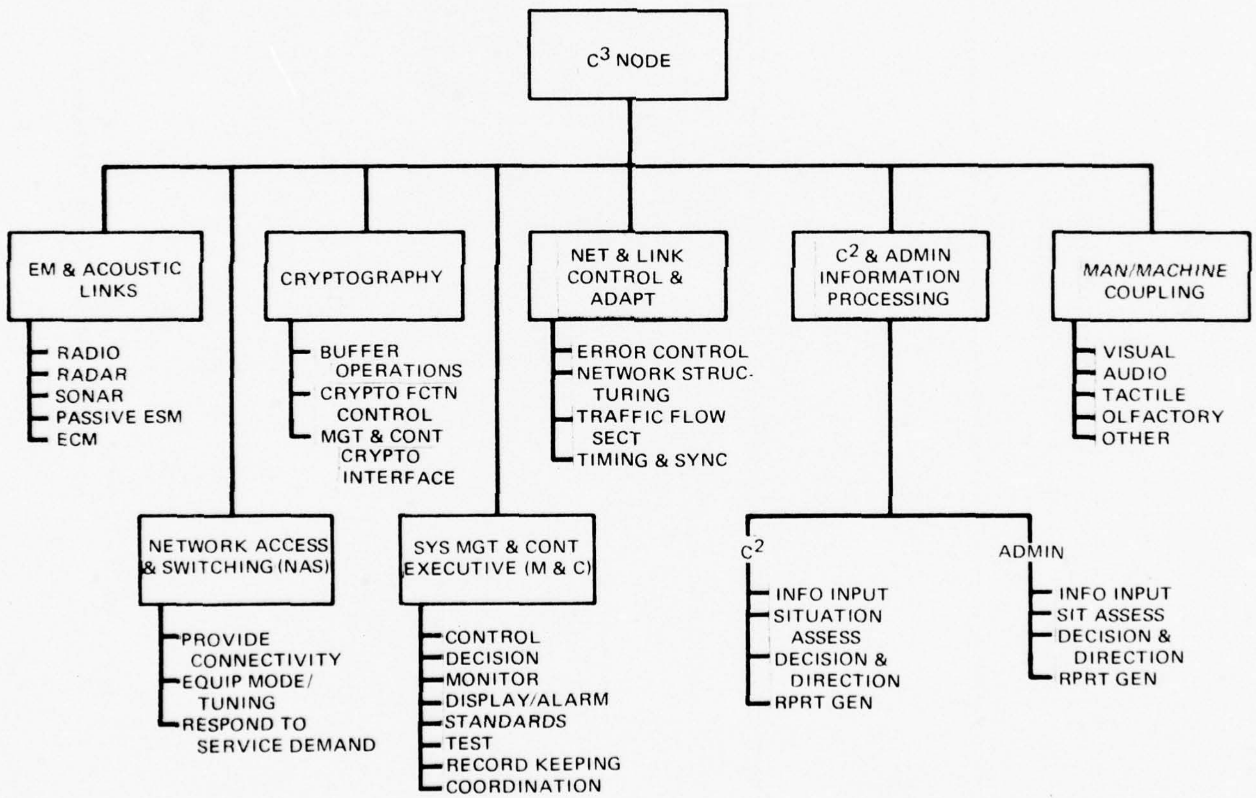

Figure 6-3. C^3 nodal functions and processes.

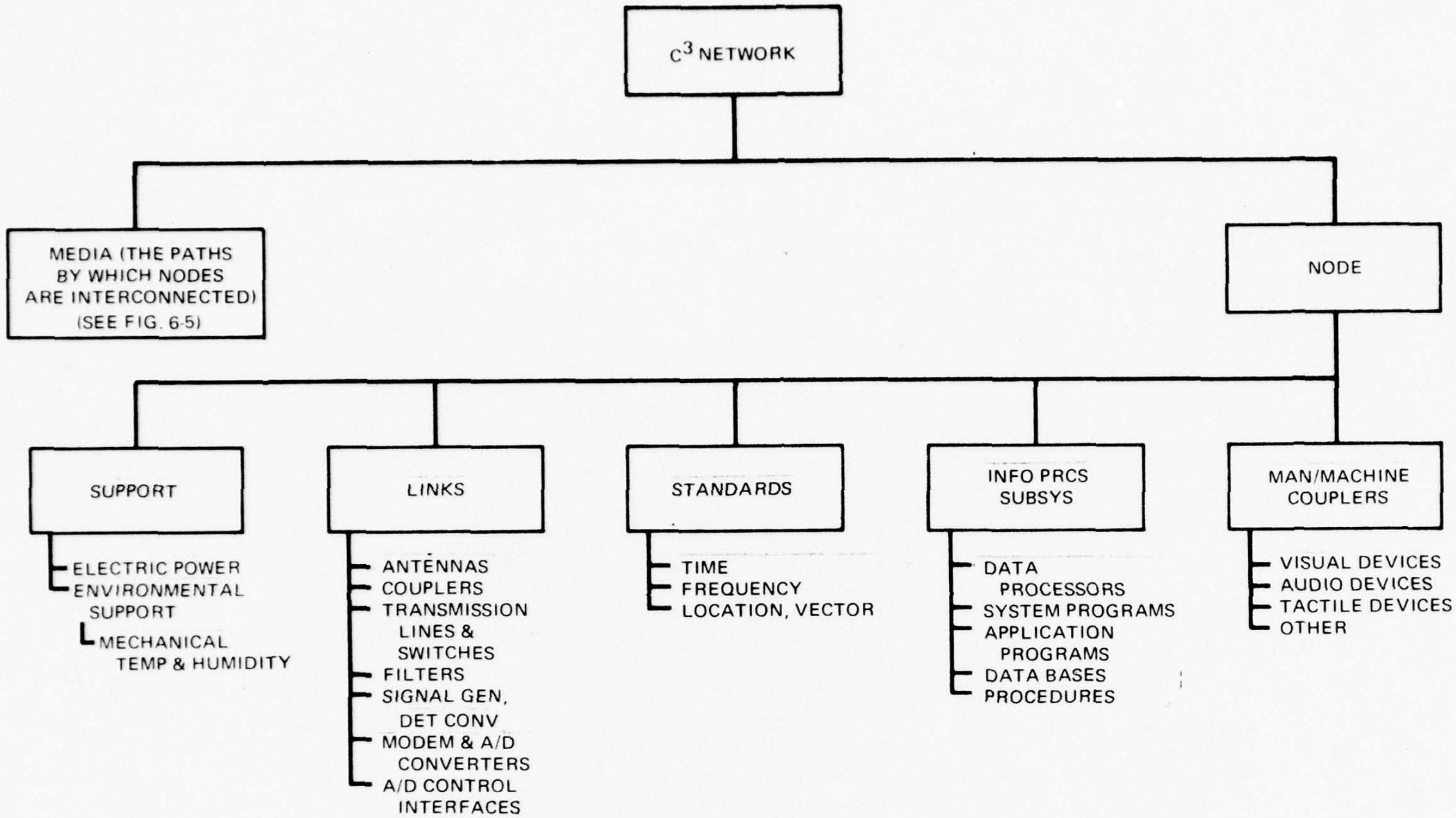

Figure 6-4. C^3 system/subsystem breakdown.

FREQUENCY \ TECHNIQUE	wire cable	waveguide	fiber optic	earth, ionosphere duct	surface wave	surface/inversion	layer duct	line-of-sight	tropo scatter	airborne relay (ELOS)	satellite relay	surface relay	direct pressure wave	refracted, reflected	pressure wave	water em path
elf				X	X											X
vlf				X	X											X
lf	X			X	X											
mf	X			X	X											
hf	X			X	X	X	X	X				X				
vhf 30-70 MHz	X			X	X	X	X	X	X	X		X				
115-162 MHz								X		X						
uhf 225-400 MHz	X				X	X	X	X	X	X	X	X				
Lx Band	X	X				X	X	X	X	X		X				
shf		X					X	X	X	X	X	X				
ehf		X					X		X	X	X					
electro-optical			X				X		X	X	X	X				X
acoustic						X						X	X	X		

Figure 6-5. Media matrix of links in terms of frequency and technique appropriate for use in NC^3N.

Figure 6-3 is a system functional breakdown of the node.

Figures 6-4 and 6-5 illustrate the partitioning of the C^3 system into components (subsystems) which either exist (natural propagating media) or are constructed.

The node is shown to be divided into five such subsystems. The media are best divided into a two-dimensional matrix as illustrated in figure 6-5, in which the check marks in the matrix indicate the media linkages of interest to the Navy. A methodology for evaluating and selecting the media mix is introduced in appendix B.

These breakdowns are the structured checklists for specification of what is to be done (functions) and what is to be constructed (subsystems) at each node. A detailed functional checklist and functional descriptions are given in appendix C. The subsystem checklist and description for a distributed hardware/software network architecture for nodes are also given in appendix C.

A C^3 node is further defined as including the totality of the electronic installation aboard a platform or shore site. In many cases there may be more than one C^3 center on

a given platform (eg, a flagship on which a flag-level and a ship-level C^3 node could be considered to exist). For purposes of a unified design, a single C^3 node will be considered to exist in such a case and the two or more C^3 centers will be called information centers of the single node. This is consistent with present usage which refers to such centers as Task Force Command Center (TFCC) and Combat Information Center (CIC) for example.

Many of these nodes will be temporary. That is, many are nodes only when launched or deployed from a mother node (eg, an aircraft launched from and later recovered by a ship). When not deployed, such nodes either become part of, or are included in, the mother node, or they simply become quiescent. When the assets of such a node become part of the mother node or are electronically active within it, they must be part of, and included in, the unified design of the mother node. This is necessary to ensure electromagnetic compatibility.

Organizational and semantic restrictions are imposed by the concept; for example, "radar systems," "sonar systems" are disallowed. The conceptual framework requires that subsystems* be organized so that they closely parallel the breakdown illustrated. This allows design work to be organized around functionally and technologically similar areas and eliminates the conceptual fragmentation which for example results in input/output devices or information processing being specially developed for use with radar, sonar, and EW.** A complete approach is desired to the problem of integrated handling of information regardless of where derived.

Figure 6-6 shows the information flow and interface concept within the node. This is basically the unified concept for the gathering, processing, and dissemination of all data and information within a node.

The processing is represented by six blocks in the figure (a seventh would be added if flag planning and battle management functions were required).

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*Eg, a "subsystem" conceived as a satellite information exchange subsystem is disallowed because it is not consistent with the functional boundaries. Communication services and subsystems are not congruent (ie, no "voice subsystem" exists to provide voice service). System attributes and subsystems are not congruent (ie, antijamming attributes are embedded in the subsystems required to contribute to such a capacity and there exists no "antijam subsystem"). User communities and subsystems are not congruent (eg, specialized subsystems will not exist for intelligence-information transfer, but dedicated networks could be formed, by configuring NC^3N assets appropriately, if at a given time and place such a network is the most effective means for the information transfer)

**A further constraint is that real subsystems must consist of mutually exclusive sets of objects. This is so that, when the top-level system manager begins to partition the system, he can ensure a nonoverlapping division of labor and specialization without the need for excessive coordination among different design organizations

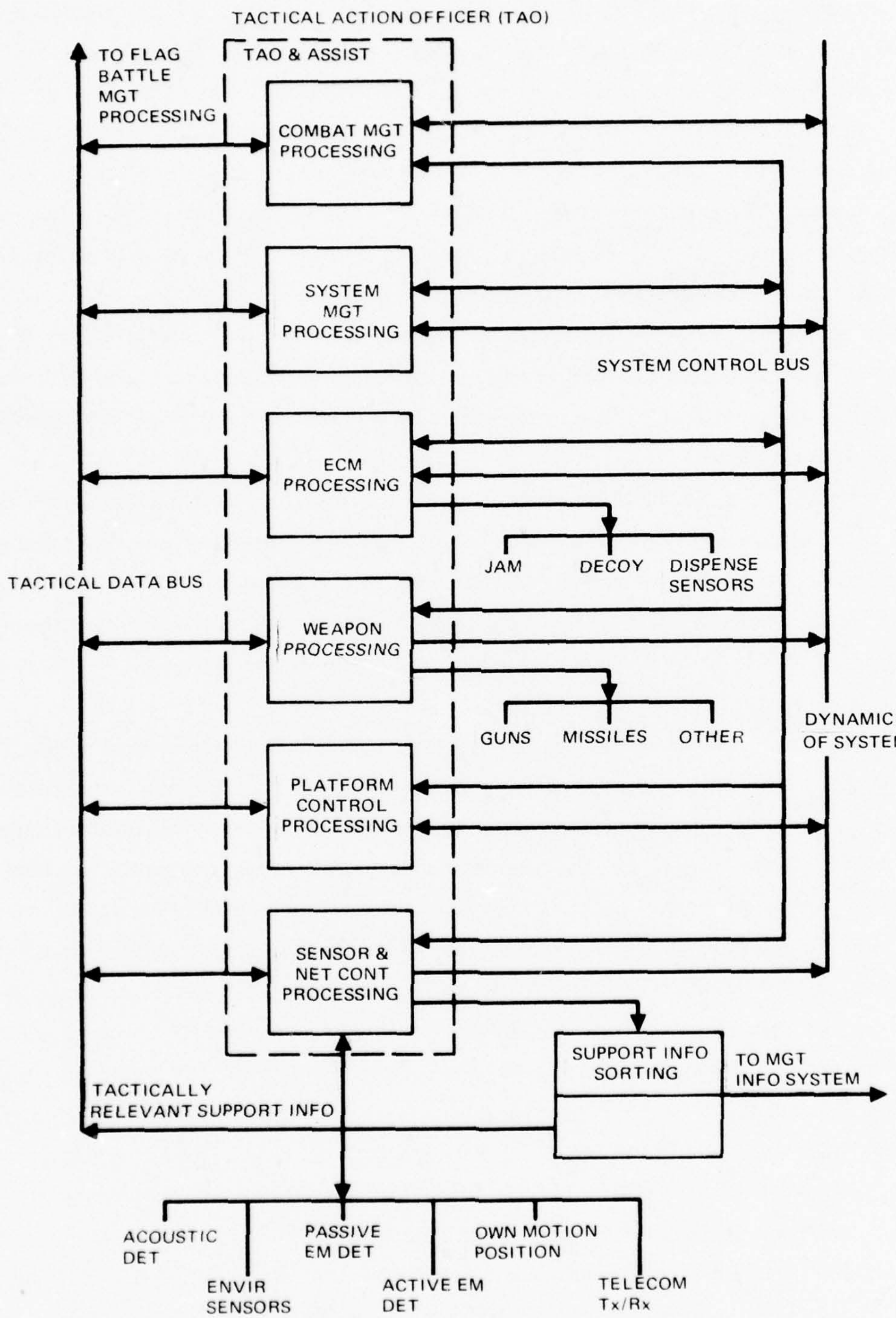


Figure 6-6. C^3 information flow on a platform.

Sensor and network control processing supervises the operation of the transmission/reception (sensors, communication nets, etc) capability of the node and performs the multi-source data correlation under the supervision of the battle management processing.

Platform control, weapons, and ECM processing functions use the correlated data as appropriate either for control of own platform or control of weapons and ECM.

System management processing supervises the correct operation of the entire electronic system within the node including system initiation, correction of aberrations, and supervision of system integrity (eg, against enemy EW).

The combat management processing incorporates those functions necessary for the overall tactical coordination and supervision of the other functions and is under control of the Tactical Action Officer (TAO) in the case of a ship or the Naval Flight Officer (NFO) in the case of some aircraft.

Support information is fed into the support information functional area (see fig 6-8). Logistic and personnel information is part of the support information area. Selected support information is then fed back into the tactical functions to support tactical decision making.

The implementation of the processing functions is modularly distributed through a node with clusters formed around users having common interests (ie, CIC, TFCC, Navigation Bridge, etc).

The trend is for electronic technology to become even more pervasive in the transmission, manipulation, and storage of information. Areas outside the present domain of electronic system design will inevitably become enmeshed. Figure 6-7 illustrates functionally some of the considerations. On the command support side of the figure, five possible information centers are postulated for a large ship. C^3 architecture must eventually examine these matters in detail to (1) determine the extent to which electronics will permeate the functional areas shown, (2) define for each platform type the best way to combine, segregate, and distribute all categories of information based on requirements for space and manpower saving, responsiveness, recordkeeping, etc, and (3) determine the best total system technical solution based on an integrated approach to all information handling requirements. Note that figure 6-7 also shows the possibility of a high degree of interlacing between the various categories of information. (For example, the tactical decision maker may need, in the CIC data base, selected information out of the material-maintenance-information files for on-board aircraft before he can make a decision on immediate commitment of airborne aircraft. He needs to know in real time what resources are in reserve when he commits forces to combat.)

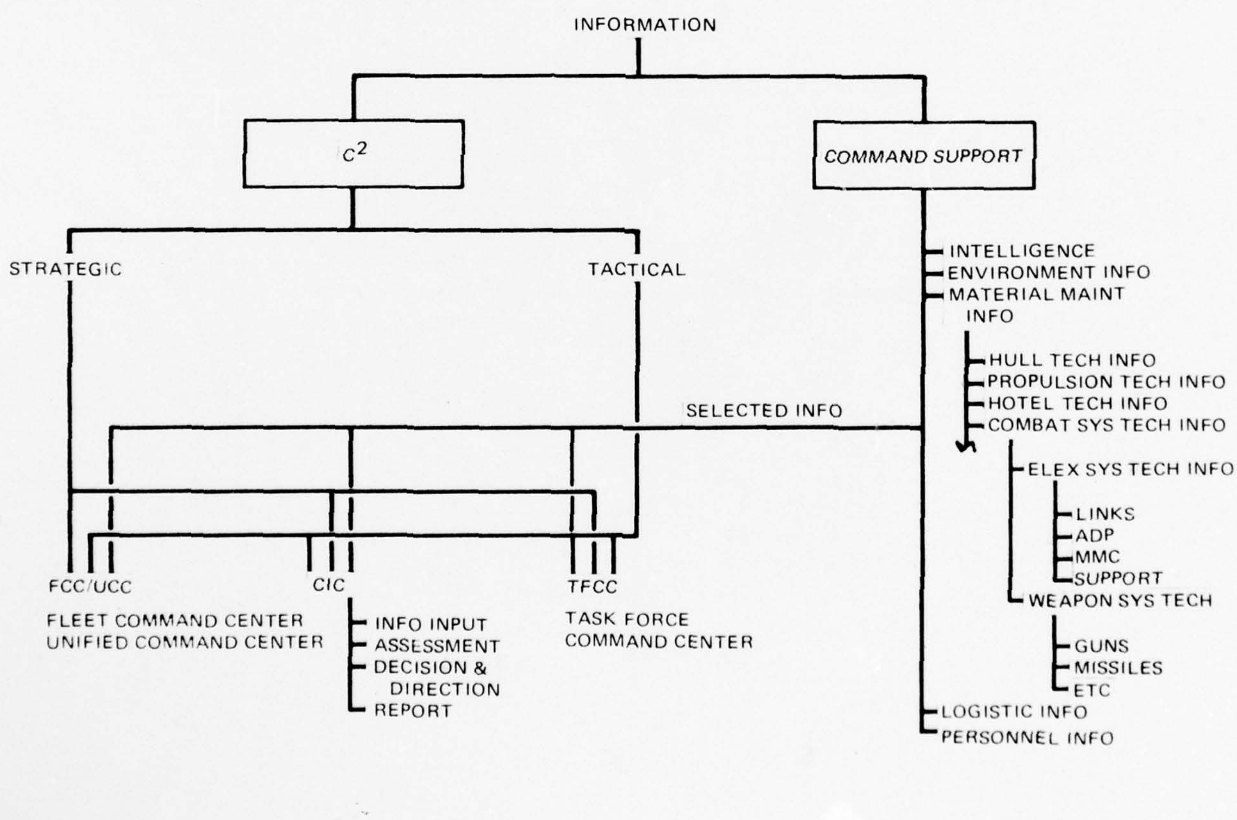
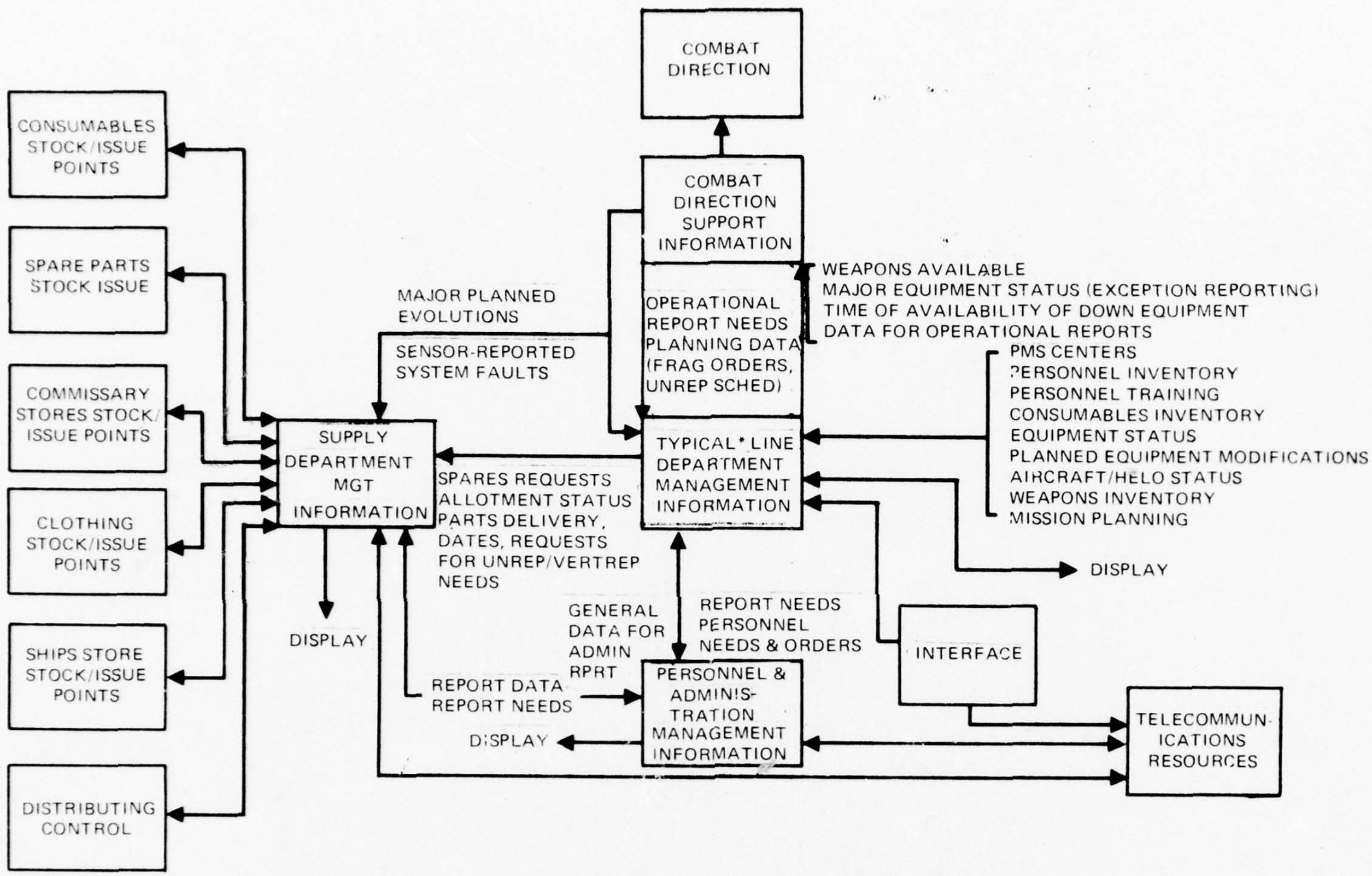


Figure 6-7. Example: information partitioning and interrelationships.



* NOTE: IN SMALL SHIPS DEPARTMENT FUNCTIONS MAY BE COMBINED OR ALL FUNCTIONS PERFORMED IN THE COMBAT DIRECTIONS SUPPORT INFORMATION PROGRAMS AREA.

Figure 6-8. Typical platform management information flow.

Even such information as equipment technical manuals may eventually become automated in electronic files if low-cost, hard-copy readout and recycling of hard-copy material becomes possible. This would reduce the huge amounts of paper materials stored on ships.

Figure 6-8 shows the conceptual information flow for command support (or management).

The key to achieving all this is hardware/software interface standardization through the NC^3N.

6.2 Netting Principles and Features

6.2.1 Guidance Issues

The C^3 framework for the NC^3N has been described. This section will now delve into some of the critical architectural considerations for guiding future network designs. This includes a brief discussion of some basic design features and principles. Then section 6.3 will list the postulated user requirements and broadly describe the types of networks which will satisfy the requirements.

Appendix D addresses principles of automatic orderwire by which the NC^3N is controlled; and appendix E addresses issues of network integrity, orderwire, connectivity, reliability, availability, NC^3N state information, routing, directory, synchronization, and standardization of bit rates. Also included will be discussion of methods of operating the networks.

The details, concepts, and assertions need further examination by system engineers and must be translated through system engineering into integrated system designs, which will be the basis for future implementation programs and new technological initiatives.

The basic NC^3N features are sequentially listed in table 6-1. Except for items 9 and 10, the implementation of each item on the list is predicated on prior implementation of all the previously listed items. When an end-to-end NC^3N exists which incorporates all these features, then the essential technical objectives* of the C^3 architecture will have been achieved. A high-level Navy policy decision is required which says, in effect, these are NC^3N features which will be implemented.

Supporting technical material for table 6-1 is presented in appendix E.

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*The future NC^3N will be computer oriented. Even for voice nets, computer intervention for control will become common. "Lessons learned" on computer oriented networks such as ARPA, MERIT, TYMNET and others indicate that the major problem to be faced in the future NC^3N will be managerial (people, resources, networks) rather than technical (ref 2)

[2] NBS Technical Note 805, *Network Management Survey*, Ira W Cotton, 32, 47, 71-80 February 1974

TABLE 6-1. PRINCIPAL C^3 NETWORK DESIGN FEATURES.

PROVIDE IN SEQUENCE:

1. CENTRAL KERNEL ON EVERY PLATFORM: TIME, FREQUENCY, LOCATION, MOTION VECTOR, CRYPTO, UNIQUE ADDRESS

   (To ensure the necessary self-knowledge to allow participation in highly dynamic operational situations)

2. CLOCK START CRYPTO, ALL BITS COVERED THROUGHOUT NC^3N INCLUDING WEAPONS GUIDANCE AND SURVEILLANCE NETWORKS

   (To ensure that the enemy cannot characterize or take control of a network by mimicking control signals)

3. JOINT SERVICE STANDARD ADAPTABLE RF SIGNAL FORMATS

   (To allow interoperability and to combat SIGINT)

4. MULTIMEDIA CONNECTIVITY FOR P = 0.99 OF SUCCESSFUL MESSAGE DELIVERY

   (Because no single path is expected to be 99% available under hostile conditions)

5. AUTOMATED UNBLOCKED ORDERWIRE CAPACITY FOR EVERY NODE

   (To ensure that no node is blocked out of the C^3 system)

6. SYNCHRONOUS DAMA* *OPERATION ~~OF~~ HIGH-DUTY-CYCLE NETS GOVERNED BY PRIORITY*

   (To ensure that critical messages are delivered and that nets operate at high efficiency during crisis)

7. FRONT-END PROCESSING TO PROVIDE COMMON NETWORK TRANSACTION FORMATS, ACCESS PROCEDURES, ERROR CONTROL, AND SWITCHING FOR GLOBAL INTEROPERABILITY OF US FORCES

8. NAVCOMMSTAs TURNED OVER TO DCS AS PART OF AN INTEGRATED SHORE-BASED MILITARY COMMUNICATIONS NETWORK WHICH IS NOT DEPENDENT ON FOREIGN BASES FOR ESSENTIAL GLOBAL CONNECTIVITY

   (To ensure survivability and flexibility through planned redundancy at lower cost)

9. DISTRIBUTED PROCESSING NETS

   (To provide a natural balance of data processing and transmission workload through the C^3 system)

10. MICROPROCESSOR, MICROCOMPUTER, SMART TERMINAL ARCHITECTURE

    (To provide the needed increase in processing power and flexibility at reasonable cost)

---

*Demand assigned, multiple access

In achieving the Navy C^3 objectives and capabilities listed in section 4, priorities for allocation of resources (funding, manpower) for implementation of the NC^3N should be in the following order.*

1. SIOP information
2. Tactical information
   - 2.1 Essential for effective operation
   - 2.2 Needed for safe operation
   - 2.3 Useful and affordable in sustained operations
3. Support information

This list then forces the following considerations.

6.2.2 Connectivity Issues

A simplified conceptual Navy connectivity graph is shown in figure 6-9. The graph shows the connectivity from NCA to the unit in the field at sea or in the air. A sample Air Force connectivity is shown to represent a parallel service connectivity. The NCA, the Navy command, and operational support centers ashore are shown embedded in the DCS network. The DCS network also provides the interface with the mobile units through what is labeled DCS LAND/MOBILE AND SPACE SYS INTERFACE. Interoperability of various nodes or command centers with the DCS network, and other nodes in the network, is provided by the use of standard front-end processing.

Further considerations which must be treated and quantified in detail during future system engineering are as follows:

- Front-end processing must include capability for preprogrammed reflex action to automatically forward or relay some predetermined classes of information toward the destinations.
- Conceptually, centers which perform information generation, evaluation, or correlation such as shipboard Tactical Support Centers (TSCs), High Level Terminal (HLT), Evaluation Centers (ECs), Ocean Surveillance Information

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*This statement on priorities is not trivial in view of, for example, the immense expenditures on a FLTSATCOM program which does not have features necessary for priority items 1 or 2 but only for 3 and possibly 2.3. (A variation of this concept was first proposed by the Bell Telephone Laboratory NTS study team in 1974.)

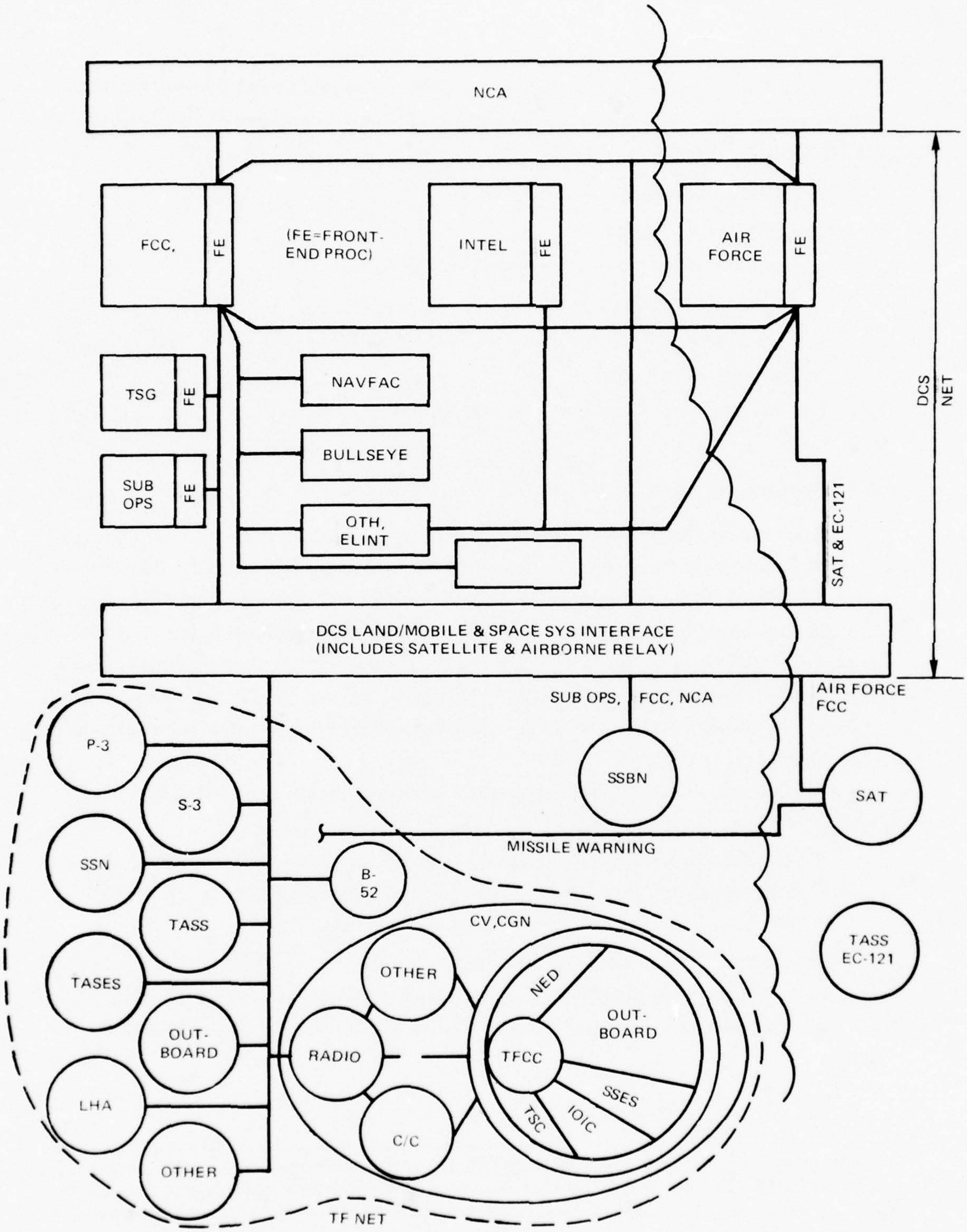

Figure 6-9. Navy connectivity graph.

Centers (FOSIC, NOSIC, etc), and ASW centers should be treated as front-end processing centers for NCA, Unified Command Centers, FCC, and TFCC even though they may be in widely separated locations. This implies that any command center may directly tap (through the network) any information center without relying on an intervening command center. This is necessary for survivability reasons alone (time sensitivity of information, and nodal vulnerabilities).

- The processing must be distributed in the network and interconnected in such a way that the network can perform its functions despite a localized failure (or even many of them). This includes the ability of terminals to communicate via the network with processing centers despite the failure of a local processing center.

6.2.3 Implementation Issues

a. Data Base Development

In addition to the future NC^3N, it must be noted that all information services within, between, and among platforms and commanders will also be computer-oriented. This statement has two major implications: (1) There can be no artificial boundary that limits naval telecommunications thinking to the confines of the communication center. This includes the capability to join on an interactive or store-and-forward basis with major information centers. (2) The Navy must design the NC^3N for information transfer for complete user-to-user service to satisfy future needs and demands. In order to accomplish this monumental task, a data base administrator must be selected. He, together with his staff, must create the concepts, policies, and plans for the computer-oriented information and data transfer and management. This can only be accomplished by continuing interaction with the operating and staff departments as well as with the technical experts. It carries with it a significant commitment of both time and money. Industry's experience has shown that 5 years is required to create and implement a satisfactory data base (see appendix F).

b. NC^3N Control Concept

Control is the activity, carried on via the NC^3N resources, to organize and configure the NC^3N at all levels, based on plans of the users. It concerns itself with such things as network and node configuration, coordination between nodes, and status monitoring.

This control is accomplished by way of established connectivities either within or among nodes, with signals or messages which are a subset of the totality of information exchange.* This information is appropriately addressed to control points of the NC^3N.

*The characteristics of such messages must, however, be distinctive enough to ensure their unambiguous identification

The priority of control traffic is above that of the associated user traffic. Its accuracy must be an order of magnitude above and its availability slightly higher than that of the associated user traffic. The system will always be designed so that at whatever the level the system is being attacked or is failing, the control signals are the last to be lost at a given level of precedence.

Control takes place at two levels. The higher level is that resident in the control and management functional area of the node. This might be considered the executive level. It is concerned with:

- Initiating or starting-up the system, based on a management furnished plan, including selection of connections, algorithms, equipment, and processes for routine operations and the necessary internodal coordination and status updates.
- Identifying and correcting aberrations from normal operations (faults). This includes dealing with occurrences which fall outside the capability of the routine processes, such as resolution of nonroutine resource contentions. Alternate connections, equipments, or processes would be chosen by the executive.

The second level is the routine and repetitive supervisory-type activities which are called for and constrained by the control and management functions, but which are resident in the other six functional areas (shown in fig 6-3). Routines include switching and routing algorithms, responses to routine user requests, error control algorithms, network protocols, data queuing and clocking, anticipated and programmed responses to natural or man-made events in the propagating medium (such as jamming), and invoking standard security and access procedures.

c. Control Features Required to Satisfy Management Objectives

In an environment of increasing threat and advancing weaponry, acceptable operational reaction time is now a fraction of what it was in the past. In order to effectively control, the NC^3N management must anticipate the need and plan for the development of responsive nodes capable of rapid and efficient adaptation. This is the key to a responsive network. Such adaptive control must include the following:

- Automation of nodal functions must proceed in a manner such that failure of automatic equipment does not inhibit the ability to invoke backup procedures* for critical functions.

*The trend must be to automated backup procedures

- Certain functions of some nodes may be subordinated to those of another controlling node. Therefore, various configurations of control at nodes must be compatible with each other to the extent that they may be operated in a functional hierarchy to exchange information, accomplish relays, and perform similar interactive functions. Nodes must know their status and environment,* and must be capable of formatting and interpreting coordinating messages sent between nodes to convey this.

Nodes must be capable of applying overhead to identify information for use at both destined and intermediate relay nodes opening opportunities for multiplexing and adaptive routing which do not presently exist.

- Nodal control functions relating to the in-service performance of the node must be performed in operational time without in any way degrading network performance or availability.
- Control must be capable of influencing nodal operation in varying modes including adaptation to unanticipated conditions affecting its operation.
- Controls should be designed cost effectively so that:

  Measurements are made in periodic samples as infrequently as possible.
  Only significant shortfalls are given attention.
  Results are meaningful without need for further manual translation.
  The information is addressed only to people who must act on it.
  It is simple and timely, and operates by exception.
  It is focused on action and not on what is interesting, oriented to self-control.
  It does not handle unusual or unpredictable events; it only identifies them for special treatment and ensures that they do not clog the normal process (ref 3).

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*Ie. both natural and man-made effects such as propagation or enemy jamming.

[3] Drucker, PF. Management, p 217-230, 494-504, Harper & Row, 1973

6.3 NC^3N User Data and Information Exchange Network Requirements and Performance Criteria

A brief general description of postulated US Navy data and information transfer services required for ships and aircraft at sea to perform Navy missions is given in appendix G. These requirements are supported by extensive requirements studies which drew on inputs from fleet personnel and analysis of crisis occurrences which are the most stressing known drivers of data and information and transfer needs. Summaries and a bibliography of these requirements analyses are included in appendix G.

These required data and information transfer services provide, along with sections 6.1, 6.2, 6.4, and 6.5, the rational basis for the proposed specific user network architectures described in section 6.6. The summary table of these requirements is extracted from appendix G and presented in section 6.6 so that the requirements and network design proposals can be more easily correlated by the reader.

In addition to data and information transfer within the NC^3N, there is a requirement to specify kinds, location, and quantity of input and output of the network.

Inputs are:

Data derived by radar, sonar, ESM techniques, and human observation
Information and data links to non-Navy networks
Undesired jamming and spoofing by an enemy
Undesired natural and man-made noise or interference

Outputs are:

Desired information and data via links to non-Navy networks
Undesired outputs which allow intercept by an enemy
Undesired outputs which cause interference to non-Navy networks
Desired outputs to allow exploitation of enemy networks by using knowledge of signal formats and network protocols to jam or spoof. (A major requirement of the NC^3N is to be able to interface with the enemy C^3 network to the extent of inducing desired uncertainty and error in his decision process.)

The specifics of these NC^3N input and output requirements are beyond the current scope of this C^3 effort. Some general principles are worth noting, however.

- The distributed network, smart terminal architecture implies that the maximum possible amount of data reduction and processing into information should be

done as close to the input to the network as possible. This is to minimize the cost of transporting and managing large volumes of data in the network.*

- The process of gathering and transferring information by active means makes the individual platforms vulnerable to attack. Therefore, platforms having high economic value should not be subjected to performing unique C^3 functions which will result in SIGINT being able to single them out as being of high value.
- Electromagnetic emissions from one platform should not expose friendly platforms to detection by bistatic detection techniques.
- The enemy will concentrate counterattacks on the platforms which attack his surveillance and C^2 capability. Therefore, these platforms should be low cost, and difficult to attack. High-value units should be provided with jammers and spoofing capability only for last-ditch self-defense.
- The major mobile command centers will typically be located on high-economic-value platforms (the large ones), and they will be disseminating a large volume of information. To prevent an enemy from using SIGINT to identify which are the command centers, the network must have a reasonably balanced signal flow and standardized signal formats. What this implies is that the smaller platforms will appear to be as active as the larger ones. Such a balance can be achieved naturally in a distributed network in that the command centers, although they are handling a lot of information, are not transmitting a lot of data; and, while the smaller platforms are transmitting little information, the data rate is high because the data reduction and information correlation process is incomplete. In other words, signal balance in the network is achieved by a proper and natural balance of signal processing capability so that the more information going out of a node, the more prior information processing has been applied to each information set to reduce the data rate.*

It should be noted that all current installations as well as the planned AEGIS violate one or more of the above principles.

*Asterisked items above amplify on OPNAVINST 5200.23, enclosure 2, section 1.a.(2), which states in part "The policy of the Navy is to relieve afloat forces to the maximum practical extent of information processing functions."

6.3.1 Performance Criteria and System Implications

a. Survivability

(1) Each commander and his staff will have the ability to assume command control of additional forces:

(a) when assigned in the normal course of events, or

(b) when the normal commander has been rendered incapable of exercising his authority.

Implications: NC^3N design must include provision for transferring command-unique data bases and processing capabilities to selected alternate platforms/sites.

A related issue is that of determining which shore-based and shore-terminated tactical support systems will be redirected towards surviving afloat commanders and what critical elements of data/information will be provided by those systems when an afloat commander has assumed ocean area command.

(2) Major afloat commanders now operating from CV class platforms may be required to operate from non-CV platforms.

Implications: System design must minimize space and weight requirements to permit installation of flag command centers in at least CG class ships. The design goal must provide for minimizing the manning level of commanders' staffs without degrading operational performance.

Issues surfaced here are those of identifying the cognizant command echelon and importance level of data base elements, decisions relating to their location in the system, and their accessibility by commanders.

The first implication inherently contains a second. System design must provide for a control mechanism and procedures which will automatically recognize the planned or unplanned loss of an information input or output terminal/node. The mechanism must automatically present, from among alternatives, the system or network configuration having the highest probability of providing the service necessary to meet critical information exchange requirements. At the node level, this includes protection against data base loss in the event of a catastrophic system failure together with a capability for rapid restart. It must also provide for automatic notification to other net members when such a failure has occurred.

b. Flexibility/Adaptability (from ref 3)

"Military considerations have emphasized the truth of the following four statements:

(1) Sensitivity, change, innovation, and adaptation are essential characteristics of tactical warfare.

(2) Policies and procedures must be tailored to the characteristics of each limited war environment, and must be continually adapted to changing tactical situations.

(3) The characteristics of sensitivity, change, innovation, and adaptation are essential at the highest level of national policy making, in all the practices and procedures of a tactical command system, and also in the tactics employed by small task units in actual combat.

(4) In any one war, the practices, procedures, and tactics that are appropriate for a particular grouping of task units at a particular time and place may be inappropriate for similar groupings of task units in a different part of the area of operations or during a different phase of the war."

Implications: (from ref 4)

"From these four statements it is evident that the designer of a system of information exchange within a Joint Task Force must be continually striving for adaptability. Further, it is equally evident that many types of adaptability will be needed; for example, in the pattern of information flow, in the speed of response, in the geographical distribution of network capacity, etc."

"An important type of adaptability is the localized application of techniques that achieve a desired result at the cost of a reduction in traffic capacity."

"For example, during a critical phase of an operation, a commander may be willing to sacrifice a great deal of communications capacity (for a brief period) in order to achieve the concealment of a small amount of information exchange with and among forward task units. The system designer, therefore, must attempt to provide this capability by some adaptation of equipment modes and/or operating procedures. Further, the adaptation must be localized, so that other users of the system may continue to operate in a normal manner.

[4] The statements on Flexibility/Adaptability are excerpted from Mitre Corp report M70-97, *A Concept for Selective Access to Tactical Information*, WG Welchman, March 1971

"The ability to conceal transmissions from the enemy, as and when it is necessary to do so, is an important characteristic of an optimum system. A more general characteristic is that adaptive emergency measures must be an integral part of the overall system concept. Here the word "adaptive" indicates that the system must permit different levels of sophistication to be used for different purposes. (A high level of sophistication will impose various types of sacrifice, such as a more complex organization, more noncombatant personnel, etc)."

"Further characteristics of an optimum system of access are adaptive measures to deal with degraded conditions of radio propagation, with enemy spoofing, and with attrition. Again, the use of the word "adaptive" is important. If, for example, a few task units are being affected by enemy jamming, it should be possible to ease their problem by adapting equipment usage or system procedures. This adaptation will probably reduce the rate and/or volume of information exchange with and among the task units being jammed. However, it should be possible to localize the employment of the antijam measures, so that task units not affected by jamming may use the full information handling capacity of the normal mode of system operation."

c. Vulnerability

(1) The system will provide physical and procedural protection against intrusion by unauthorized parties, alarms if such intrusion should take place, and protection against spoofing by entry of false directives or information.

(2) The system must be capable of operating in hostile electronic environments in a manner which allows continual service without identifying specific targets, forces, or their locations, and without permitting an enemy to ascertain own force intentions.

Implications: System design must provide for selection and implementation of counter modes of service on recognition of prespecified thresholds of electronic attack, and for instituting those counter modes without prior notice to other net members. Concomitantly, it must provide for automatic reconfiguration of node equipment and procedures to recognize and accept these new modes. Further, design must preclude determination by an enemy of system loading levels, modes of operation, or derivation of information content.

d. Interoperability

(1) Each node of the system will be provided the inherent capability to access any other node in the system as well as selected non-NC^3N nodes on a demand-access basis. Such accesses must be transparent to the user through standard protocol.

Implications: System design must provide for accessibility to any node by a senior not normally in the chain of command, and seniors must be accessible by NC^3N nodes on a situation-demand basis. Under certain circumstances, this direct access may be effected by means of commercial or other non-Navy assets.

Data bases in the 1985 era will be composed of general service and compartmented information. Contingency realignment of command structures, from time to time, will demand that alternate commanders have access to information heretofore denied them. System design must therefore provide for a high degree of interoperability in accordance with such realignments, but without compromise to the security and integrity of information contained in the data bases.

The NC^3N must be compatible with Worldwide Military Command Control System (WWMCCS) procedures so that direct access can be effected from the platform level when a situation so demands. It must also be compatible with evolving Joint and DCS systems (JTIDS, AUTODIN II, unit level switch, DSCS) as well as systems being developed under the aegis of treaty organizations and international agreements.

(2) Node design, particularly tactical commanders' nodes, will minimize duplication of capabilities inherent in the platform in which the node will be installed.

Implications: Platform systems, eg, those performing combat direction, and the associated data processing suite must be accessible directly by the tactical flag node. Under no circumstances, however, will such access by the commander or his staff detract from overall platform performance.

e. Quality

Quality of information to the decision maker and to the implementer of the decision must be consistent with the operational need to: (1) raise the decision maker's level of cognition from one of uncertainty to one of estimating and accepting risk; and (2) produce the desired effect in the case of machinery (eg, weaponry)*

Implications: Quality of information depends on (1) how well the gathering and collation process is done, and (2) the fidelity with which the information is transferred. Since the future system will be primarily digital, the quality of the system is given implicit quantification in terms of bit error rates which are specified in annex A to appendix G.

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*Eg, direct a weapon with sufficiently small CEP to effect a target kill.

f. Availability

The system will be available to the user the stated time for the mission duration of the platform in which it is installed. Provision will be made for graceful (in lieu of catastrophic) degradation if major faults do occur.

Implications: As a result of tradeoff analysis, an optimum ranking of system capabilities must be determined. Included will be factors such as reliability and maintainability of equipment, manning level and training considerations, and the feasible techniques for minimizing onboard routine maintenance and fault isolation and correction. As the system capabilities lessen because of faults, design will provide for retention of capabilities on the basis of criticality of need.

g. Responsiveness

The system will respond to the urgency for information to be exchanged or processed and will establish a precedence of handling should there be a contention for system resources. Urgency levels may be assigned by a process within the system or by human intervention. The associated response time will include the selection and provision of the media of exchange and mode of presentation deemed best for transferring information between and among men and machines.

Implications: Under normal circumstances, system design will provide for automatic recognition of precedence for handling both intranodal and internodal processing and exchange of information. In recognition of the fact, however, that command may desire to modify responsiveness criteria on a situation-demand basis, the capability for human override will be provided. It should be observed that exercise of this capability will likely require internodal coordination due to the fact that some system components (notably communications links) are shared by net members at both the local and ocean level.

h. Connectivity

The term "connectivity" refers to the existence of potential or actual physical links with sufficient range to interconnect nodes of the network. Annex C of appendix E develops path redundancy criteria which would lead to sufficient connectivity to ensure 99% probability of successful message delivery when availability and quality factors were considered. In the

case of sensors, similar requirements exist to provide a sufficient number and range of links* to ensure detection of targets early enough to allow time for the processing of information and decision making. In the case of ECM, links must be of sufficient number and range to inhibit the C^2 processes of an enemy and, if possible, prevent or degrade targeting by him.

i. Usability

The system will allow semiautomatic entry and access of information by means which are familiar or which will require a minimum of operator training.

Implications: Although directly related to use of familiar man-machine interface equipment, usability requirements also dictate that system interface design emphasize procedures commonly in use. This implies that any procedural translation from the understood and familiar to the unfamiliar must be performed internally by the system in a manner transparent to the user. A related implication is that the human-machine functional responsibility interrelationships must be well defined prior to the node-level system design phase.

j. Capacity

(1) The system will be capable of supporting task organization commanders or platform commanders in the conduct of mission planning as well as in command control of high-speed, multithreat tactical nuclear engagements. The system will provide the capacity to support a command structure which is solely Navy, Joint operations, oriented, or one controlled directly by a supra-authority such as the NCA. On a noninterference basis, the system should provide operational support functions; ie, administrative and routine logistics tasks.

(2) The system will be capable of tolerating increases in net membership on an ocean or local area basis caused by reallocation of forces or by a major reassignment of forces between ocean areas.

(3) The system control features will manage and operate system assets in a manner that ensures a continuing economy of resource utilization within the bounds of maximizing information throughput and minimizing transfer of noninformation.

*Eg, radar, sonar, ESM

Implications: It is obviously impracticable to design a system which would be the panacea for all the ills of command control structures, missions, and platform population forecasts. The design must be affordable and strive for a compromise between the ideal and the achievable, with emphasis on innovative procedural concepts. These concepts should focus on minimizing system perturbations caused by a heavy influx or departure of net members or by a major command restructuring.

Second, the control and monitoring capability must collect, analyze, and evaluate resource utilization data on a continuing basis and provide to decision makers alternative solutions to information flow problems. The solutions will include a statement concerning the impact on system performance of sustaining selected service at the possible expense of lessening service to other net members.

The foregoing implies that the system must be capable of automatic response to user-levied quality and speed-of-service demands, and, when conflicts arise between the two, for presenting a recommended compromise. The originator (man or machine) will inform the system what is required; the system will make the technical judgment as to how to best satisfy the requirement.

6.4 Vulnerabilities

This section lists some of the threat considerations (threats to the C^3 system) which constrain the NC^3N architecture. Appendices H, I, and J discuss these threats in some detail.

The threat considerations are:

a. Ocean Area

(1) DCS shore terminal sabotage. A bullet or small explosive charge in an antenna feed could completely disable that portion of a shore node depending on it.

(2) Earth coverage satellite uhf uplinks are easily jammed by manpack equipment at uhf. Slightly more sophisticated equipment (eg, small mobile systems) can jam shf.

(3) Nuclear effects on the propagating medium and of stresses to node equipment due to the nuclear environment. Media effects include energy absorption for ionospheric and transionospheric propagation modes that extend from elf into uhf, accompanied by changes in wave velocity, phase shift, and rotation of the plane of polarization.

The fireball region is opaque virtually throughout the entire radio spectrum, up to about 100 GHz, for several seconds. Optical electro-optic-frequency (EOF) propagation is disrupted by intense fireball luminosity.

Appendix H summarizes effects of the electromagnetic pulse (EMP) and of transient radiation effects on electronics (TREE) on the NC^3N nodes. These effects include permanent and temporal node disruption or degradation, due to damage-level energy coupling to antenna circuitry, analogous to lightning phenomena. Logic circuits may be disrupted for a variety of causes that include effects attributable to photoemission and displacement damage to semiconductors from exposure to radioactive fields. Additionally, memories may be erased either by EMP or by TREE effects.

(4) Long-haul hf is susceptible to long-range jamming and direction finding. Long range jamming can be reduced or eliminated by path and frequency management.

(5) Satellite surveillance can be expected to be capable of localizing any source of uhf or shf uplink radiation sufficiently well to provide information on search regions to higher-resolution systems.

(6) Satellite destruction is possible but least likely of any alternatives.

b. Intra-Task Force

(1) Sabotage – Less likely on ship systems.

(2) Earth coverage uplinks are highly susceptible to jamming, and TF coverage beams may still be susceptible in areas such as the Mediterranean due to restricted waters.

(3) Nuclear burst – Same as a. (3) except ionospheric path is not required and distributed ionosphere could cause multipath interference to desired groundwave.

(4) Long-range jamming – Same as a. (4) except TF using groundwave hf can avoid long-distance jammers by proper frequency management.

(5) Satellite surveillance – Same as a. (5).

(6) Satellite destruction – Same as a. (6).

(7) Local tactical jammers – These will have limited resources which will constitute a high threat to small units, on the fringes of a task force or near the immediate scene of combat, which are attempting to receive communications from more distant commanders (eg, CV to F-14 to missile links). Such threats can be combated by providing small platforms with a null or jam capability and some processing capability, and by direct attack on the jammer.

6.5 Some System Constraints

Some of the most significant constraints that must be considered in the construction of a C^3 network architecture are highlighted in this section.

6.5.1 Space, Motion, Time

a. Position and Motion

Among the most important factors in C^3 system design will be the assumptions about how accurately each node holds location and time information. In the 1980 era, satellite services will be available on a global basis which will allow nodes to passively determine their own position to an accuracy of 10 metres and velocity to an accuracy of ~3 cm/s in three dimensions. Communications links can be used to pass such information among the members of task forces and groups. Submarines and very small nodes such as boats and manpack will usually be excluded from the satellite navigation service because of size or environment, so other means (ie, communication links, inertial guidance etc) will have to provide information to aid these nodes to locate themselves.

Usually tactical requirements (eg, weapons direction) will pose stringent requirements on nodal position and motion accuracy. The main concern, therefore, is an integrated information handling approach which will ensure that these services are available for C^3 purposes including the tactical information base.

The advent of the laser gyro will eventually provide, in a small package, sufficient positioning accuracy to allow missile guidance nets handling multimissile launches from many platforms. Since guidance messages to each missile can be very short, all such messages can be fully encrypted and uniquely addressed for each missile on a multiple-access netted basis.

b. Timing

It is now technically and economically feasible to provide time of sufficient accuracy on every platform to ensure network acquisition based on internal references. Table 6-2 shows representative accuracies and costs.

TABLE 6-2. TIME AND FREQUENCY STANDARDS-CHARACTERISTICS.

Type	Long-Term Stability	Valid Period	Weight* (lb)	Size* (inches) HXWXD	Approx 1975 Cost ($)
cesium	$\pm 3 \times 10^{-12}$	(no drift)	<30	6 X 6 X 19	20k
rubidium	$\pm 1 \times 10^{-11}$	1 month	<20	6 X 6 X 16	10k
quartz	$< 5 \times 10^{-10}$	1 day	<1/2	2 X 2 X 2	0.6k

*Weight and dimensions are based on projected LSI technology for post 1985.

On the basis of table 6-2, it appears that most naval platforms should be provided with a primary cesium standard and backup rubidium standards for redundancy. Manpack radios can use a quartz standard provided it is resynchronized fairly often.

Table 6-3 relates maximum time error to stability and resynchronizing period. This is a direct result of the equation:

MAXIMUM TIME ERROR (sec) = STABILITY X RESYNCHRONIZATION PERIOD (sec)

This assumes the time error grows linearly with time. That is, since the standard has no significant drift, the time error accumulates until resynchronization.

TABLE 6-3. MAXIMUM TIME ERROR (MILLISECONDS).

Resynch Period (days)	$\pm 3 \times 10^{-12}$ (cesium)	$\pm 1 \times 10^{-11}$ (rubidium)	Notes
1	0.000259	0.00091	
7	0.00181	0.0061	
30	0.00778	0.026	
60	0.0155	0.058*	typical ship mission period
90	0.0232	0.078*	typical max mission period
182	0.0472	0.16*	
365	0.0945	0.32*	

*Asterisked values assume 10^{-11} stability is valid beyond 30-day period specified in table 6-2.

Time can be transferred from one platform to another. During signal processing an estimate of the propagation delay time is obtained from the correlation process. The difference between the estimated propagation time and the real propagation time is the relative time error of the two platforms. By correcting the time of one platform, "time"

can be transferred from one platform to another. This process could be performed regularly, say every week or so for ships and each day for aircraft. Probably only one ship or a small number of ships in the task force would then be responsible for keeping "real time."

6.5.2 Technology Constraints

a. Transmission

1. Size and weight reduction of rf components. Much of this reduction which is possible from solid-state rf device technology has already occurred. Much rf hardware is "plumbing" which is developed as far as possible already in terms of size, weight, electrical linearity, and energy loss. Cavities, coils, capacitors, transmission lines, and waveguides are about as small as they will ever get.

2. Attempts to reduce the size of rf components using ferrite and solid-state techniques often result in penalties in linearity of current and voltage paths which can lead to severe EMC problems due to intermodulation. The dynamic linearity of active devices is not expected to get much better than the present 86 dB approximately, and there are 200-dB and more differences between receiver thresholds and locally generated transmitter powers on typical naval platforms.

3. Antenna coupling is a major unresolved problem. The problem is a result of the large number of antennas that must be installed in the physically limited space of most naval platforms, interactions that exist among the various antennas due to energy at out-of-band frequencies, and, finally, the influence of many objects and obstacles of many geometrical shapes and sizes that exist aboard ships.

Some of the critical areas that must be considered involve (ref 5):

(a) Effects of obstacles on main-beam to main-beam coupling as a function of range, for in-band frequencies and for out-of-band frequencies

(b) Effects of polarization on obstacle decoupling

(c) Effects of main-beam misalignments for both in-band and out-of-band frequencies

(d) Effects of obstacles on antenna performance as a function of range and angle

[5] Project A-1301, Final Report, 31 January 1972, Contract N00024-71-C01120, Georgia Institute of Technology

(e) Intermodulation

(f) Potential phased-array problems (including intermodulation)

4. Systems engineering design methods must be improved to ensure control over design and placement of all antennas employed on a platform to avoid hazardous mutual coupling effects, to reduce electromagnetic interference to levels of acceptability, and to guard against distortion of the antenna pattern. Due to the complexity of interaction effects, the effectiveness of design methods for control of near-field effects can only be established following completion of a rigorous total systems test program, leading to a demonstrated proof of acceptable performance (ref 6, 7).

Appendix B describes the basic methodology required.

5. Antijam requirements will have the effect that some nominally omnidirectional (or at least broad-area-coverage) antenna systems at hf and above will have their radiation coverage modified by a null-on-jam capability on selected small platforms. The usefulness of such techniques is constrained by multinode multidirection linking and netting requirements.

6. Modularity and standardization should extend to electromechanical, hydraulic components. The result should be more use of lower-cost standard modules for single- and dual-axis drives covering a broad spectrum of torque, speed, and accuracy.

7. Electro-optic frequencies (EOF) will be entering into general use, allowing high-data-rate, secure, antijam, anti-intercept connectivities. EOF links to submerged submarines (from surface, airborne, and satellite platforms) will be much less limiting on their operations than present technique.

8. Nuclear EMP is an ignored problem in many transmission designs today, and, as this area gains attention, the complexity and cost of rf designs will increase.

[6] NAVELEX 0101, 106, Electromagnetic Compatibility and Electromagnetic Radiation Hazards, August 1971
[7] NAVORD OP 3565/NAVAIR 16-1-529, Hazards of Electromagnetic Radiation to Personnel

9. Link quality and availability: Most naval platforms have very complex structures, resulting in blocking and multipath cancellation of radiated energy. Em noise and propagation environments are also very complex. Processing power and data should become available to aid the C^3 network specialist to predict the quality and availability of any given connectivity in real time, replacing present trial-and-error methods.

10. Small ship shf satcom capability will eventually provide additional link capacity at the cost of increased EMI due to spectrum crowding in this band and vulnerability to enemy EW.

11. Common user connectivity schemes controlled by automatic processes will replace the present vulnerable dedicated use of assets. Such processing will provide AJ, LPI enhancement; more efficient operation through more precise time, location, and motion information; and faster response to users through coordinated switched management of transmission assets.

12. Satellite on-board processing will further enhance system flexibility and resistance to jamming.

b. Processing Technology Impact

1. Microprocessor technology mushroomed in 1974. Further advances in microminiaturization can be expected to the extent of providing at least minicomputer-type capability in hand-held sizes. The buttons and displays are likely to be the limiting factors on size reductions. Size and low cost will drive processing architecture toward distributed, functionally dedicated, software/hardware. Time sharing for many functions will be minimized even though the hardware/software modules will be idle much of the time in many cases. This will decrease the complexity of executive routines and make future systems very adaptable to evolutionary change. Changes in electronic suites can be made by simply installing new distributed interface control units onto a permanent standard bussing system and running only local cables.

2. Fiber-optic or coaxial multiplexed signal distribution will, hand-in-hand with distributed processing, lead to a major breakthrough in cost, weight, and space in cabling and will again make possible redundant routing for survivability.

3. Optical processing will eventually result in pervasive direct electronic real-time access to all the information one can conceive of needing on most naval platforms. This will lead directly to a need to treat all information in an integrated total-system sense whether it is for example, equipment repair information, supply data, or tactical data. This will be eventually completed by techniques for speech communication with computers for direct data entry into tactical and other information systems using limited but natural task-oriented vocabulary and grammar (ref 8).

4. Backup procedures will be almost as fully automated as the primary procedures, and manual backup will be neither effective nor affordable in almost all cases.

5. Processing efficiencies and accurate space, time, frequency standards will lead to the availability, on a global basis, of accurate real-time information on time, platform locations, and platform vectors so that almost all platforms will have highly responsive adaptable and predictable communication network entry to communicate with any platform. It will for the first time allow real-time multimedia, multinetwork connectivity for important messages in extremely adverse wartime environments.

   The evolution to cheap data processing will result in more on-site data processing to save transmission assets.

6.5.3 Human Factors

Humans in any operational system primarily make decisions (including generation of hypotheses). Usually a human decision is not required when events occur according to a well formulated plan or design (anticipative decision making). The human, in most applications, requires aid in effectively accomplishing this decision making process. These aids either allow him to make the decision at all or augment his speed, security, or accuracy. Basically, the purpose of making a decision is to cause an unplanned event to become a planned event (the plan is amended).

Most humans, especially in the military, prefer to make decisions as much as possible in anticipation of events. It is sometimes acceptable, if the events are not too compli-

[8] Ritea, HB, System Development Corporation, Speech Communications with Computers in Command & Control (private correspondence between HB Ritea and RT Shearer, NELC, Code 0233), received March 1975

cated or do not occur too rapidly, to make decisions as they occur, but not significantly long after they occur. If events could confidently be predicted to occur within the boundaries of a plan, there would be very little reason to communicate during the planned operation. It is seldom the case, however, that sufficient resources are applied to an operation to independently cover all possible contingencies with a preplanned decision. The situation can be improved by increasing the degree of standardization or operating procedures. This should occur at two levels: the minimum standard level which will allow interchange of personnel in the same job category; and the advanced level where a high degree of coordination is achieved because combat team integrity has been maintained for a sustained period of time. The goal should be that the advanced procedures are not inconsistent with the minimum standard procedures.

In order to achieve the most operating capability, a given team member must know not only his own operating procedures, but the procedures of the other key team members as well. In addition to this, he must know what phase of the mission the platform is in and the operational readiness status of the major platform systems. That is, the team operating procedures could change substantially as a function of these two factors. A good measure of team effectiveness is that the operating procedures and discipline are at such a state that only essential information is communicated. That is, "chatter" is eliminated. This helps illustrate the point that many times an individual must contend with too much information in the decision making process.

The system must be designed so that information saturation cannot occur either to the system or to decision makers. It also follows that in order to achieve a high degree of standardization of personnel procedures, the equipment configuration must also be standard. Every nonstandard configuration requires further training in order to achieve the desired effectiveness. While it may be desirable to assign a person into different job categories as preparation for a higher-level job, it is also desirable to perform cross training in order that the individual understands to a certain degree the entire operation at his level. Otherwise, it is possible that the actions of one individual team member could critically interfere with the operation of another. In order to avoid information saturation of a person at a higher level in the C^2 hierarchy, this lower-level coordination becomes increasingly important. That is, "the bubble" (operational picture) should be distributed as much as possible.

In order to set forth the required C^2 interconnectivities, the functional C^2 hierarchy must be precisely defined. This definition must include all necessary vertical and lateral coordination. Only in that way can human roles be evaluated. The underlying philosophy is that humans communicate primarily by exception and preferably by voice.

Routine (preplanned) communication is the prime candidate for automation. For unplanned interaction, voice is by far the most rapid and reliable.

Many times in present design, the user of a system is forced to have a great deal of knowledge of the system in order to be effective. Future systems must be designed so that the user need only have sufficient system knowledge to effectively operate them in their degraded modes. In other words, the user should be able to concentrate on the uses and not the inner workings of his tool.

Another situation in which the human can play a major role is that in which he interacts with feedback. His senses may be stimulated (visual, audiotactile) in various manners to convey information to him. He, then, out of some combination of reflex and judgment, exerts a control force over some mechanism. In many cases, the human can perform this function very efficiently. A good example is a fighter pilot in a tactical situation.

When it is desirable to extend his basic capability by electromechanical means, a primary consideration is the nature of the interface of these systems with the human. Since the human himself is a system with feedback and a limited range of time constants, the input/output values are limited by data rate, signal strength, and other such features.

The human also typically solves problems sequentially. For example, a race car driver pays little attention to engine instruments while negotiating a difficult corner; he will wait for the straightaway to check these. Similarly, he may have the ability to adjust his suspension while moving, but he cannot do it with each bump.

There are many situations in which humans are used to augment a deficient system. Good examples of this are manual plotters and sound-powered phone relay talkers and other human intermediaries. However, using humans in this manner reduces not only speed but accuracy as well – especially if the individual has no inherent understanding of the operations sufficient for him to exercise judgment.

6.6 Proposed Specific User Network Architectures

The framework for the NC^3N was established in section 6.1 and the basic principles and features were described in section 6.2. The essential C^3 network design features were given in table 6-1. Given the user requirements, the threat and constraints established in sections 6.3, 6.4, and 6.5 and their supporting appendices, it is now possible to proceed to propose specific network architectures. The user requirements are summarized in table 6-4 at the end of this section.

There will be three kinds of networks which are interconnected by switching. They are:

- Ocean area coverage beyond line of sight (BLOS) networks by which mobile forces are connected into the DCS-operated global fixed network.
- Extended line of sight (ELOS) networks by which intra-task-force connectivities are provided at ranges over the horizon out to about 500 km via the ionosphere, groundwave, or satellite relay paths.
- Line of sight/ELOS (LOS/surface and airborne relay ELOS) networks by which task force connectivities are provided out to 40 km for ship to ship and out to 500 km for ship to air and which provide ELOS by surface or airborne platform relay.

All these nets will be constructed via a multiplicity of media to ensure the required 0.99 probability of successful message delivery in the face of outages due to both natural and man-made events.

a. Ocean Area Net

This is constructed of satellite and ionospheric paths interconnected among themselves and into DCS via packet switching. DCS will own the satellites and shore assets and the Navy will own the mobile terminal.

The globe is conveniently divided into four ocean areas:

Atlantic and Western Mediterranean
Mediterranean and Indian Ocean
Western Pacific
Eastern and Central Pacific

A global network tying mobile platforms into DCS would be composed of four overlapping subnets covering the ocean areas.

The assets of the four subnets would be intertied via cables and satellite relay, backed up to some extent by point-to-point hf and vlf/lf. Four synchronous-orbit satellite locations are required. The satellites would be tied together via satellite-to-satellite optical links. Areas above 70°N could be covered by two or more high-apogee, near-polar-orbit satellites.

The backbone of the ocean coverage net will be shf satcom jam-protected (note 1) 2.5-degree beams which will each cover about a 1600-km-diameter area. Eleven of these beams would provide simultaneous major crisis coverage for 11 task forces which might be, for example, in the following areas (but switchable to other areas):

Western Atlantic, Caribbean, Greenland-Iceland-UK (G-I-UK) gap,
Middle and Eastern Atlantic, Western Mediterranean, Eastern Mediterranean,
Indian Ocean, Western Pacific, Northwestern Pacific, Northern Pacific,
Eastern Pacific.

Three 2.5-degree beams on each satellite (except for the Atlantic satellite, which requires five) would more than satisfy the demand.

An additional area coverage beam on each satellite would provide low-data-rate service to units outside the crisis areas covered by the narrow beams. This would provide jam-protected service at high data rate on the shore-to-ship link and 75-bps jam-protected return (ship-to-shore link).

The shore-to-ship paths would have, for each satellite, up to 32 TDM 2400-bps channels. The ship-to-shore path would be thirty-two 2400-bps FDM channels. Groups of mobile units assigned to a common mission or task would be assigned one of the FDM channels to operate as a common user group* with DAMA protocols capable of providing 5-30-s response time for all tactical voice and data (including tactical intelligence) and still having capacity for general service and special intelligence traffic (flash through routine) as well as some facsimile. Most platforms including P-3 will need two channels – one for data and one for voice. For example, the P-3 will need to join one of the ASW voice coordination nets** in the ocean area and simultaneously need tactical data access for ASW and related tactical purposes.

With the shf backbone described above, the ocean area requirements items listed in table 2-1 of appendix G are all satisfied for mobile units having the terminals*** except items 1-G, L. The sub and P-3 to shore LPI requirements are satisfied to the extent that it will be difficult to correlate shf radiations with any given platform as long as all platforms are using the same signal formats.

The mobile units will require a 1-metre parabolic antenna. It should be no larger to ensure that space and weight problems do not militate against providing shf satcom services to DE and FF size ships.

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*The memberships in the groups will be limited in size to ensure acceptable response to service demands.
**This requirement listed as item 1-M in table 2-1 of appendix G.
***The mobile unit will require a steerable 1-metre parabolic antenna or equivalent.
Note 1: Limited to large platforms (FF or larger). Also limited by EMC with EW and weapons guidance installations, and danger of exploitation by ARM. Jamming may reduce rate per ship to 75 bits per second (bps) and stop all services except for brief tactical and strategic messages. AJ could be provided by null-steering, spreading the 75 bps in a 2400-bps signal and frequency hopping in the 32 FDM channels.

To ensure that the requirement for 0.99 probability of successful message delivery is met and to satisfy disadvantaged users, the shf backbone sub network will be complemented as follows:

1. A 2400-bps serial broadcast via synchronous satellite with an shf jam-protected shore-to-satellite link and an earth coverage uhf downlink servicing mobile units with 0-dB antennas. A 75-bps uhf ship-shore satellite link should be provided for orderwire and DAMA ARQ.*

2. An hf backup half-duplex DAMA netted operation supported by high-power shore transmissions of frequencies in groups of five which can be used in subnets of one or more frequencies for half-duplex operation on demand of mobile platforms (1200- or 2400-bps operation on each hf assignment). This operation will be supported by a major DCS communications station with at least two associated DCS radio stations in each ocean area. A demand assigned LPI 75-bps (note 2) mobile unit to shore capability should be provided as part of this capability. This capability will provide backup service satisfying all the user ocean area requirements, except items I-G, L.**

3. Shore to mobile unit jam-protected broadcasts on vlf and lf from at least two stations in each ocean area. This provides capability for requirement items I-E (note 3).

4. Optical and ehf satellite net providing survivable and AJ/LPI connectivity with submarines as prime customer (note 4).

5. To satisfy requirement L, it is probable that the shf satcom will have to add one narrow beam per ocean area and three 200-kbps channels per ocean area. In addition, the ship terminal may need at least a 4-metre-diameter parabolic antenna if some jam protection is desired.

6. Requirement item L cannot be satisfied via foreseeable technology. The requirement can be satisfied out to about 400 km on an LOS basis by using shf or millimetre wave point-to-point links.

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*The orderwire and ARQ capability for the uhf satellite broadcast should also be available through other ship-shore links. The uhf uplink is not jam protected. Each ship joining the uhf satellite broadcast is assigned 1 second every 2 minutes with which it can request more capacity on the ship-shore link, if needed.

**Requirement items referred to are those of table 2-1 in appendix G.

Note 2: Antijam and LPI, though technically feasible, are very expensive except for limited protection.

Note 3: At lf and below, the available data rate is limited by the bandwidth of the transmitting antenna.

Note 4: Optical communication is limited by cloud cover in areas where terrain results in very thick cumulous-type cloud formations. For submarines, additional data rate limitations will be imposed by submarine depth and attenuation due to suspended particles and marine life.

Network designs must ensure that an attack on one capability does not produce collateral damage. (Eg, shf and hf assets ashore must be widely separated and linked so that several links and nodes can be destroyed without fragmenting the net.)

b. Extended Line-of-Sight Net

This net will not only serve intra-task-force purposes but will also connect disadvantaged users into the DCS via a gateway ship. For example, a PHM is large enough to handle about one vlf/lf receiver, two hf transceivers, and two to four vhf/uhf transceivers. Except for vlf/lf capability, the PHM usually needs all of these for intra-task-force operations. Messages to or from DCS must be packet switched into the intra-task-force nets and use another larger platform in the task force as a gateway node. This net satisfies requirement items II-A, B.

Individual elements of this net are as follows:

1. A backbone AJ hf subnet capable of up to 12 kbps total using as many as five general-use 24-kbps channels for data and voice on different hf frequencies. Under jamming conditions, the net must be capable of at least 300 bps on one spread-spectrum/frequency hop rf link while the remaining three or four narrowband channels are used for additional or redundant data/voice transmission. The net should be capable of being used in an adaptable way so that platforms under different degrees of jamming get different service from the network at a given time. Typical members of this net are ships, large aircraft, amphibious command vehicles, and vans, and occasionally submarines. The hf links should provide range out to a minimum of 160 km (up to 480 km). Several additional voice channels are required on large amphibious ships for amphibious operation. In addition, one or two inter-TG voice channels are required on TG command ships.

2. The prime backup element for the hf subnet is the shf satcom. Intra-task-force messages can be packet switched into the packet stream of the FDM ship-shore link for delivery via one of the uhf satellite broadcast, the shore-ship TDM links of the shf satcom, the shore-ship hf links, or the uhf satellite broadcast.

3. Any other ship-shore connectivity can be used as backup to relay a message (by packet switching) via a shore node of the DCS.

4. The LOS/ELOS network is the third backup and complementary network which provides ELOS connectivity via surface or airborne relay.

c. LOS/ELOS Net (ELOS via surface or airborne relay)

The LOS/ELOS network provides the primary connectivity for ships operating within 40 km of one another and ship to air out to 500 km. It also provides complementary coverage to hf at ELOS with Lx band and uhf (225-400 MHz) using relay.

1. An Lx band subnet operating at up to 50 kbps which is AJ protected. This subnet will be operated according to a scheme evolving for the ITNS/JTIDS-II. This will include extensions via the E-2, S-3, and P-3 type aircraft to high-performance aircraft (such as the F-14), to ground combat zone air controllers, and occasionally to escorting SSN. This net may on occasion be supported by high-altitude, long-range RPV (Compass Cope) launched from shore (especially in high-threat areas such as the G-I-UK gap, the Mediterranean, and the Northern Pacific).

2. A uhf band (225-400 MHz) (the uhf growth radio program) subnet for backup secure voice/data for ship-ship, ship-air service. This will include CATCC services and aeronautical emergency (243 MHz). This subnet must be organized in a way which will prevent ESM from identifying CATCC traffic as unique to a CVA.

   Additional services for Amphibious Air Strike support and Navy special warfare such as UDT are to be provided in this band. Backup ship-ship, ship-air service may also be required in this band.

3. A vhf band, 30-76-MHz net will be provided for amphibious operation, small craft control, amphibious command vehicles, and shore fire control (note 5).

4. An optical scatter mode subnet which as a minimum will provide 75-bps data extension to SSNs operating at depth.

Note 5: The tactical data nets at hf & Lx band together have sufficient capacity to handle digital messages designating targets and calling for weapons support for amphibious related purposes. However the need for both voice and data service on a time-shared basis, the limited weight-carrying capacity of the ground controller who must usually carry the radio on his back, and need (in many cases) for over-the-horizon connectivity will probably limit the solution to vhf/uhf (ie, 30-76 MHz – for ground/ship connections; and 225-400 MHz – for ground/air connections). Data entered via vhf/uhf should be switchable for broad distribution as required on the main data nets.

5. A multiplexed optical data loop, ship-to-ship, for very-high-data-rate weapons coordination by ships in close company involved in close-in defense. (Close company means ship-ship links of approximately 10 to 15 miles.)*

6. Shf, millimetre and/or optic links air (LAMPS) to ship, weapons direction, S-3 or P-3. These are limited-use, point-to-point links. Assets supplied for item (5) above are sufficient for some links on time-share basis.

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*1 statute mile = 1.6 km (approx)
1 nautical mile = 1.8 km (approx)

TABLE 6-4. NAVY USER DATA TRANSFER AND NETWORK REQUIREMENTS. (SEE APPENDIX G FOR SUPPORTING DOCUMENTATION.)

	Type	Rate (bps – one way)	Recommended Mode	Net* Time	Note
		I. OCEAN AREA COVERAGE			
A.	Graphics-General	2400	DAMA FDX	10 min	(1)
B.	Record-All Services	4800	DAMA HDX	30 s	(2)
C.	Tact Data and Intel.	4800	DAMA HDX	5 s	(3)
D.	Voice (Seat of Govt)	2400 (2 per ocean area)	DAMA HDX	30 s	(4)
E.	Shore-Sub, Ship	75	SIMPLEX	5 s	
	Shore-TACAMO	75	SIMPLEX	5 s	
	OMEGA, LORAN C, other	5 × 75	SIMPLEX	–	
F.	Allied Bdcst	75 (typ) Variable	SIMPLEX	30 s	
G.	Very-high-resolution Fax Recon A/C-CV, LCC, LHA	2 per ocean area @ 1.5 × 10^6 minimum (5 to 6 × 10^6 desired)	SIMPLEX	10 min	
H.	TFCC-FC/SC Fax & Data Exch	One per task force @ 50K	DAMA FDX	10 min	
I.	SAR Voice	Variable	DAMA HDX	1 min	(5)
J.	Sub-Shore LPI	2400	DAMA HDX	1 min	
K.	P-3 Shore LPI Fax & Data	2400	DAMA HDX	10 min	
L.	TASS to Shore	3 × 200 Kb/S	SIMPLEX	full period each link	One link per TASS ship
M.	P-3; S-3, REC, MEC, NAVFAC, FHLT, TASS, etc, ASW EVALUATOR VOICE NET.	2 × 2400 b/S Per Ocean Area	DAMA HDX	30 s	
		II. BLOS/ELOS INTRA TASK FORCE			
A.	Tact Data (up to 1 ea/TG) (including graphics)	4 per ocean area @ 9600 each	DAMA HDX	5 s	(6)* (10 min for graphics)
B.	Voice: TF/TG, TG, SAR, UNREP, HICOM, amphib	5 ea/TG @ 2400	DAMA HDX	5 s	(up to 5 addl 2400-bps circuits for Amphib Com ships troop radio)

*Net access time is average allowed time delay for highest-priority message expected. Message precedence is correlated with allowed delay time (eg, under item II, A has a 5-s response time except for graphics, therefore, graphic packets are transmitted on a "space available" basis on this net)

TABLE 6-4. NAVY USER DATA TRANSFER AND NETWORK REQUIREMENTS (Continued).

	Type	Rate (bps – one way)	Recommended Mode	Net* Time	Note
			III. LOS/ELOS TF/TG		
A.	Air Ops CV Voice/Data	4 X 2400	DAMA HDX	<1 s	(7)
	Air Ops DLG Voice/Data	2 X 2400	DAMA HDX	for final	
	Air Ops LHA/LPH Voice/Data	2 X 2400	DAMA HDX	approach	
	Air Ops Small Ship Voice/Data	1 X 2400	DAMA HDX	otherwise	
	Air Ops SCS Voice/Data	2 X 2400	DAMA HDX	5 s	
B.	ASW/AAW Strike Ship, Air Voice/Data				
	CV	16 X 2400	DAMA HDX	5 s	Max 16 subnets per TG
	CG	7 X 2400	DAMA HDX	5 s	for item 8 distributed among
	LCC/LHA	5 X 2400	DAMA HDX	5 s	ships as indicated
	Small Ship	2 X 2400	DAMA HDX	5 s	
	Very Small Ship	1 X 2400	DAMA HDX	5 s	
C.	Lamps/Sonobuoy/P-3/S-3A Data and Raw Sensor (Relayed to ship such as DD, DE, PF except S-3, P-3 have on-board processing)	Up to 31 3-kHz channels	SIMPLEX	5 s	Requires command link to sonobuoys
D.	ASW/AAW Ship-ship voice/data	2 X 2400	DAMA HD	5 s	
	SAU, SAR, UNREP, Misc	1 X 100K			High-speed (1-s response time) data net for cooperative close in ASMD)
E.	TASES to Ship/Ship to TASES	129k	FDX	continuous	One link per TG flag
F.	Amphib Ops	up to 3	HDX		ea A/C assigned to one
	Gunfire Air Strike support	2400 per TG			2400-bps subnet
	(Ground-Air) Support Voice/				Up to 16 subnets (in addition
	Data all ships DE, PF, & larger	2 X 2400	DAMA HDX		to 2 gunfire support nets), dis-
	Other: Large Amphib Voice/Data	16 X 2400	DAMA HDX		trib on amphib ships as shown
	Other: Med Amphib Voice/Data	10 X 2400			for control of assault craft &
	Other: Small Amphib Voice/Data	6 X 2400			helo via both LOS & over the
G.	Maritime Ops & Safety				horizon 20 to 50 km
	All Ships	1 Analog Voice	DAMA HDX	(mf/hf)	
	All Ships	1 Analog Voice	DAMA HDX		162 MHz
	All Ships	1 Analog Voice	DAMA HDX		115-156 MHz
	All Ships	1 Analog Voice	DAMA HDX		243 MHz (8)
H.	Weapon Control	1-75k per TF	DAMA HDX	1 s	

TABLE 6-4. NAVY USER DATA TRANSFER AND NETWORK REQUIREMENTS (Continued).

GENERAL NOTES

(1) DAMA FDX = Demand-assigned, multiple-access with full-duplex operation at each node. DAMA HDX = DAMA with half-duplex operation at each node (HDX is stated as minimum requirement and FDX is not excluded where HDX is stated). When voice is digitized, the digital rate is assumed to be 2400 bps.

(2) For very small ships the ship-shore-record traffic can be guarded by another small or medium ship and relayed via a TF/TG data net when required.

(3) Serves 100 ships total (25 per ocean area) CV, CG, LCC, LPH, SSES, IOIC, TFCC plus VQ aircraft.

(4) This service is normally provided only to medium and large ships. Small ships will reassign assets normally assigned to TF/TG voice. This service may require 16-kpbs channels until voice quality of 2.4 kbps improves.

(5) Mobile assets reassigned from other services.

(6) Graphics transmission requirements on this net are TFCC to TF/TG ships. This requires maximum 2400-bps capacity and then only during periods when TF/TG is not under high threat, heavy attack condition which would require most of 9600-bps capacity for fast-response nongraphic data.

(7) DAMA on LOS, ELOS is for nets with high-duty-cycle protocols on wide-bandwidth nets such as proposed for LX band – may use statistical orthogonality based on coding in lieu of DAMA.

(8) The 243-MHz LOS ckt is monitor only. When Tx required, the transmitter is reassigned from other use.

(9) The listings of table 6-4 do not as yet include requirements for multisensor bistatic surveillance and target designation networks and links such as laser and TV target designation.

7.0 COMMAND CONTROL PROCESSES AND RECOMMENDED POST-1985 CAPABILITIES

The purpose of this section is, first, to highlight the processes that the commander and his staff must go through as a system user to obtain information, assess the situation, decide, and generate reports and directives. (These processes are the Information Processing (IP) and man/machine coupling (MMC) functions of the node). Then, a set of required capabilities will be matched against these processes and also allocated to the subelements of IP and MMC.

7.1 Functional Definition

The command functions in the Navy C^3 Network may be conveniently characterized in part in terms of four basic functional categories:

Information input
Situation assessment
Decision and direction
Report and directive generation

The command control processes specified in Naval Warfare Publication (NWP) 11-1B are grouped into these four categories in the following functional analysis.

The implementation of these functions at the various nodes will be dependent on:

The nodal mission and location within the command hierarchy
The time frame in which the node is viewed (eg, 1980, Post 1985)

However, the functions themselves are invariant with respect to node and time frame, and can be characterized by inputs, processes, and outputs which are generic in nature and nodally independent.

This allows the functional description of a baseline or reference node to be used as the framework within which architectural issues will be addressed. Those issues will relate to the methods by which the reference nodal functions are implemented at the various NC^3N nodes. Detailed functional descriptions are given in appendix C. Figure 7-1 shows the relationship of the basic command control functions within a node. The information input function* is the front-end processing function, which, in effect, prepares the information for use by a man in either the situation assessment or decision and direction function. The situation assessment function is the function in which own force missions and tasks are analyzed with respect to own and enemy capabilities and potential

*A specified subset of the information input is tasking, which is discussed in section 7.7.1.

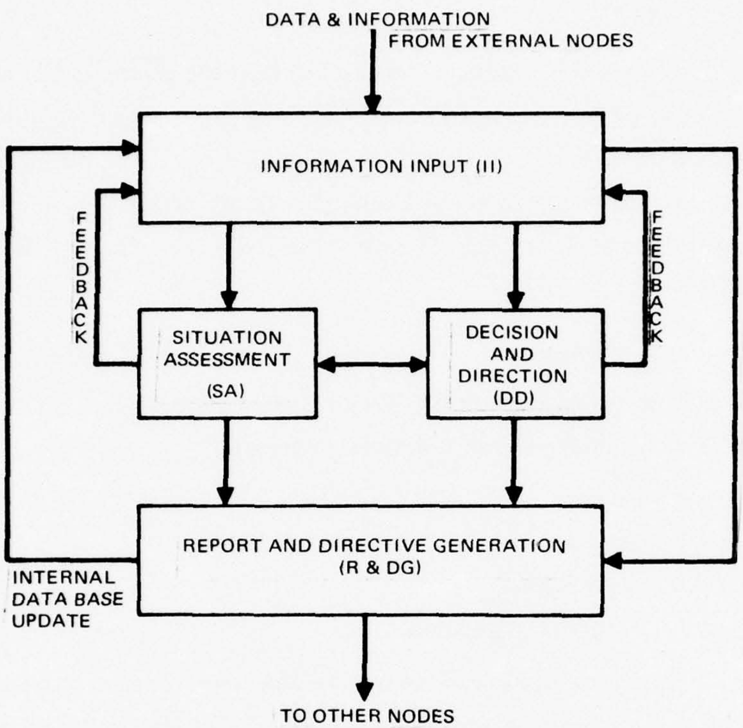


Figure 7-1. Nodal functional relationships.

enemy courses of action (COA). The resulting estimates of the situation become the major input to the decision and direction function. Situation assessment is a continuous monitoring and evaluation process, and its results may modify existing data base information or create new information. This is shown by the feedback loop from SA to II.

The decision and direction function formulates and analyzes alternative courses of action to accomplish assigned tasks and missions in the face of potential or actual opposition. Since the output of the DD function may change the operational assignments/status of assigned assets, figure 7-1 shows a feedback loop to II. In addition, a two-way link is shown between SA and DD to illustrate that a dialog between these two functions occurs on a continuing basis.

The report and directive generation function provides the processes by which a command node passes information, orders, alerts, queries, and requests to external nodes. The function is not confined to handling information developed after a particular decision has been made; it provides a means of immediately outputting, to cognizant commands, critical information received and identified by the II or SA function.

It must be mentioned that these four basic functions are performed continually, beginning with the mission planning phase and proceeding through monitoring and evaluation of operations to eventual mission termination and results analysis. Furthermore, the processes outlined to carry out these functions are invariant within this continuum. They apply as is, during planning, execution, and immediate postoperational review and analysis.

7.1.1 Tasking

In a broad sense, tasking at any level in the NC^3N hierarchy can be considered as a particular class of information inputs. Tasking is always generated at a higher node in the command echelon than the particular node in question, and becomes an integral part of the node's data base via the information input function. Examples of data base information in the tasking category are:

Objectives
Mission (Fleet/Force/Group/Unit)
Specific tasks
Plans (EMCON, communications, etc)
Rules of engagement

The formats in which tasking is received by a node are time-frame dependent. For example, presently, tasking is received in the form of OP-ORDERS, OP-PLANS, Letters of Instruction (LOI), Employment Schedules (EMPSKED), and messages including NTDS force orders. In addition, tasking in the form of tactical orders and maneuvering instructions at sea is communicated primarily over voice radio circuits and in ATP-1 volume 2 (Allied Naval Signal Book) code formats. However, this may not be the case in either the 1980 or post-1985 time frame.

Tasking is unique as a class of information input because it provides a nodal thresholding mechanism, and is used in establishing the following:

1. Internodal connectivities – what network or networks the node will function within
2. The data base files and elements the node will maintain
3. The set of operational procedures and applications programs the node will utilize
4. An initial set of conditions to be reviewed and evaluated during performance of the situation assessment function

5. Primary input to the decision and direction function, in which specific determination of how the tasking is to be implemented is accomplished

6. Setting thresholds on the report generation function as to frequency and routing of reports, as well as defining content requirements

In summary, the utilization of tasking information permeates all four of the basic functions, appearing as inputs to each in a form dictated by the requirements of the individual function.

7.1.2 Interfunctional Flow

In order to conceptually integrate the four functions in terms of information and subfunctional flow, an all-inclusive representation (fig 7-2) was developed which expands figure 7-1 in a flowchart format derived from the information processing functional description of appendix C. Read top to bottom and left to right, the sequential and internally iterative nature of the C^2 process is illustrated in a manner which highlights the relative contribution of each function, in terms of output, to the overall process.

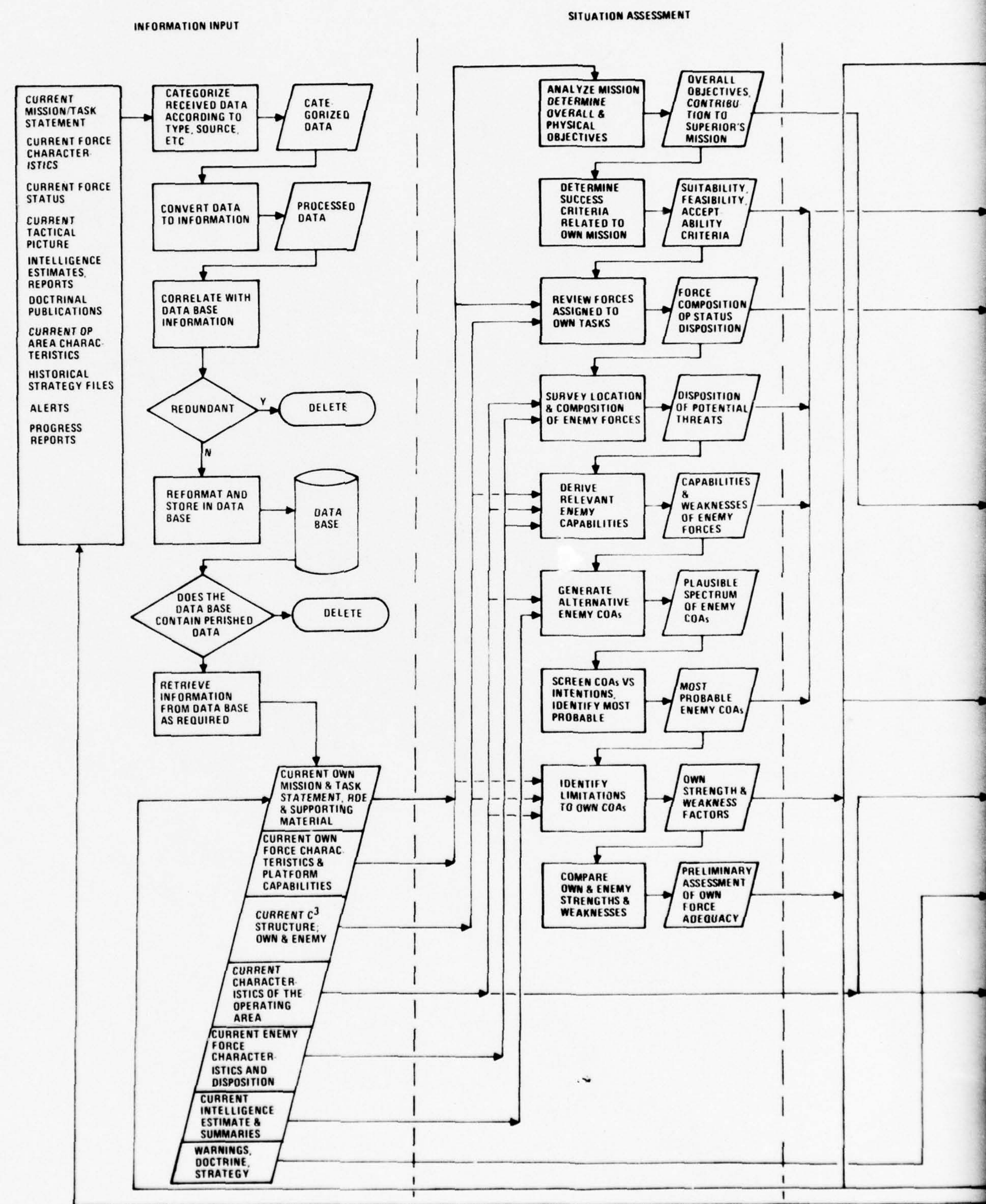
Also apparent are the inherent dependencies of each function upon the others for its input. This observation extends even to the information input function, which receives substantial feedback from report generation in the form of internal data base updates.

A major observation not readily apparent is the iterative nature of the process as a whole; that is, the four functions are performed in a continuous sequence throughout the course of a given mission, with the number of iterations, and the time required for each, situation dependent. Taken in total, the four functions encompass all relevant aspects of command control and provide a baseline for structuring the post-1985 NC^3N architecture along functional lines.

7.1.3 Rationale for the Generic Functional Approach

The purpose of developing the foregoing description of a generic reference node is to provide, through an explicit statement of functional commonality among all nodes of the NC^3N, a framework within which architectural issues of the current, 1980, and post-1985 time frames will be addressed. Recognizing that these issues relate primarily to the means by which the basic functions are implemented, the observation that implementation is inherently node and time-frame dependent led to the adoption of the following documental guidelines:

a. The functional description must be sufficiently generic to represent any node in the NC^3N from FLTCINC to platform level while, at the same time, sufficiently detailed to minimize ambiguity concerning functional boundaries.


INFORMATION INPUT
SITUATION ASSESSMENT
CURRENT MISSION/TASK STATEMENT
CURRENT FORCE CHARACTERISTICS
CURRENT FORCE STATUS
CURRENT TACTICAL PICTURE
INTELLIGENCE ESTIMATES, REPORTS
DOCTRINAL PUBLICATIONS
CURRENT OP AREA CHARACTERISTICS
HISTORICAL STRATEGY FILES
ALERTS
PROGRESS REPORTS
CATEGORIZE RECEIVED DATA ACCORDING TO TYPE, SOURCE, ETC
CATEGORIZED DATA
CONVERT DATA TO INFORMATION
PROCESSED DATA
CORRELATE WITH DATA BASE INFORMATION
REDUNDANT
Y
DELETE
N
REFORMAT AND STORE IN DATA BASE
DATA BASE
DOES THE DATA BASE CONTAIN PERISHED DATA
DELETE
RETRIEVE INFORMATION FROM DATA BASE AS REQUIRED
CURRENT OWN MISSION & TASK STATEMENT, ROE & SUPPORTING MATERIAL
CURRENT OWN FORCE CHARACTERISTICS & PLATFORM CAPABILITIES
CURRENT C3 STRUCTURE; OWN & ENEMY
CURRENT CHARACTERISTICS OF THE OPERATING AREA
CURRENT ENEMY FORCE CHARACTERISTICS AND DISPOSITION
CURRENT INTELLIGENCE ESTIMATE & SUMMARIES
WARNINGS, DOCTRINE, STRATEGY
ANALYZE MISSION DETERMINE OVERALL & PHYSICAL OBJECTIVES
OVERALL OBJECTIVES, CONTRIBUTION TO SUPERIOR'S MISSION
DETERMINE SUCCESS CRITERIA RELATED TO OWN MISSION
SUITABILITY, FEASIBILITY, ACCEPTABILITY CRITERIA
REVIEW FORCES ASSIGNED TO OWN TASKS
FORCE COMPOSITION OP STATUS DISPOSITION
SURVEY LOCATION & COMPOSITION OF ENEMY FORCES
DISPOSITION OF POTENTIAL THREATS
DERIVE RELEVANT ENEMY CAPABILITIES
CAPABILITIES & WEAKNESSES OF ENEMY FORCES
GENERATE ALTERNATIVE ENEMY COAs
PLAUSIBLE SPECTRUM OF ENEMY COAs
SCREEN COAs VS INTENTIONS, IDENTIFY MOST PROBABLE
MOST PROBABLE ENEMY COAs
IDENTIFY LIMITATIONS TO OWN COAs
OWN STRENGTH & WEAKNESS FACTORS
COMPARE OWN & ENEMY STRENGTHS & WEAKNESSES
PRELIMINARY ASSESSMENT OF OWN FORCE ADEQUACY

2

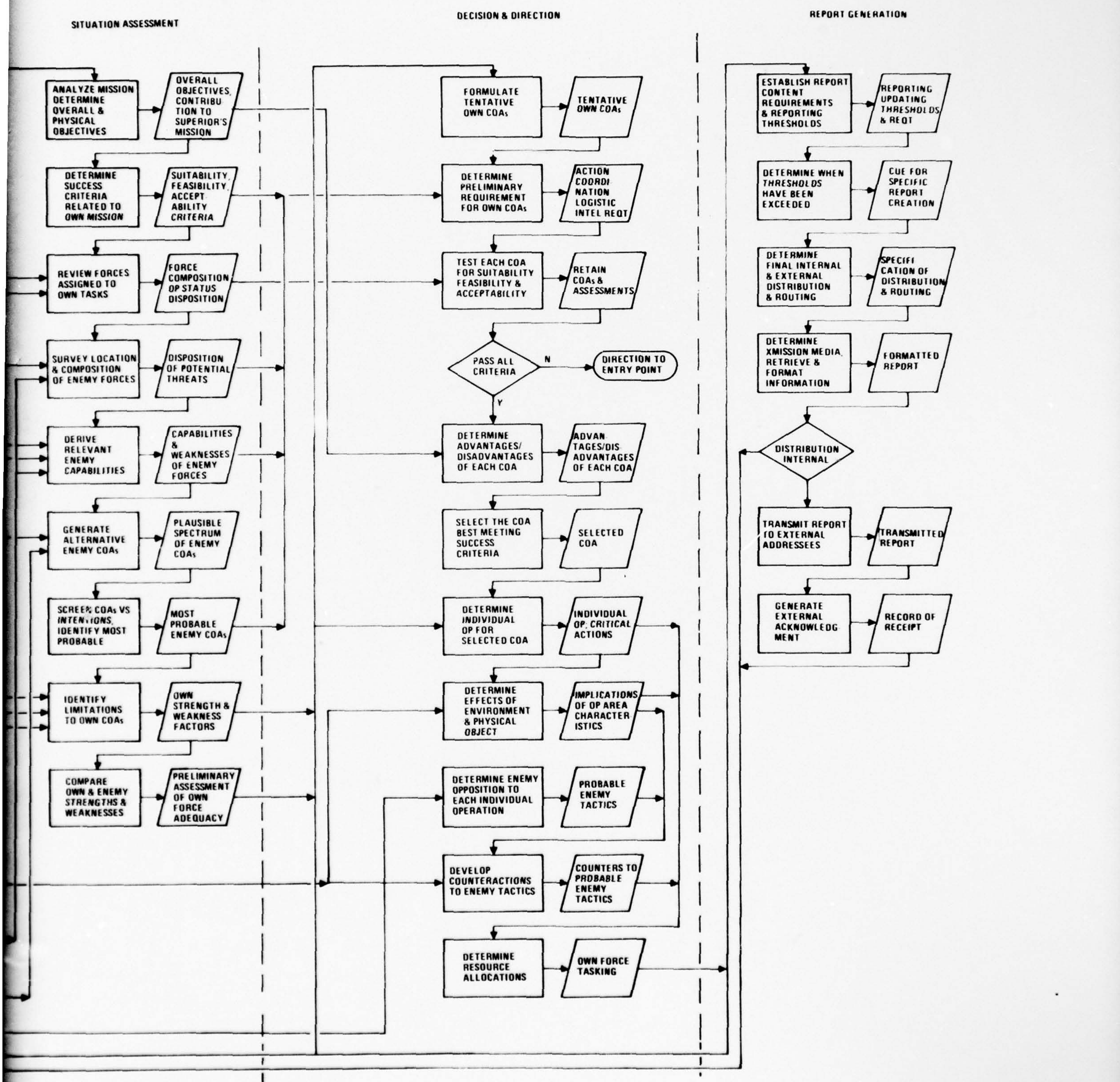


Figure 7-2. Nodal functional relationships, expanded.

b. It must provide an adequate framework so that the ensuing articulations of current, 1980, and post-1985 implementation schemes can be readily compared and relative merits manifested.

With respect to detailing the implementation of the four basic functions, the specification of the generic node serves further:

a. As a basis for bounding the scope of post-1985 command concepts and technology assessments

b. In conjunction with technology assessment to provide primary rationale for the subdivision of functional responsibilities between man and machine

c. To furnish guidance for the specification of automated operational applications programs and decision aids to support the situation assessment and decision and direction functions

In view of the foundational nature of this document, a concerted effort was made throughout its development to draw upon accepted doctrinal publications to ensure that its validity, and hence eventual usefulness, would not be open to question.

7.2 Synthesis of Alternative System Architectural Features

The following section is devoted to the systematic derivation of viable C^3 alternative architectural features.

7.2.1 Methodology

With the objective of being as rigorous as possible in developing system alternatives, the following methodology (dictated by the qualitative descriptions of architectural elements and system operational requirements) was adopted:

- Specification of architectural element alternatives
- Evaluation of each such alternative relative to each performance criterion
- Ranking of architectural element alternatives by tradeoffs among the performance criteria
- Synthesis of ranked system alternatives by system sensitivity judgments with respect to the major architectural elements
- Reduction of plausible system alternatives to a viable set judged as meeting system operational requirements

This methodology is applied in detail in appendix K.

7.2.2 Summary Description of the Selected Alternative

Appendix K describes three NC^3N architectural alternatives each of which provides, to a degree, the totality of capabilities necessary to support the four basic functions of command control. Appendix K describes these alternatives and the selection rationale in detail.

Briefly, the methodology used entailed the following procedure:

- The alternatives were specified in terms of the architectural subsystems; ie, links, information processing subsystem, etc.
- The subsystems were evaluated with respect to each performance criterion to derive the relative importance of each subsystem to each overall C^3 system performance parameter.
- Following this, subsystem alternatives were ranked by using tradeoffs among the performance criteria.
- Then a synthesis of ranked system alternatives with respect to the major subsystems was performed.
- Finally, plausible system alternatives were reduced to a set judged as meeting system operational requirements.

The alternative, System I, was ranked the highest. The system features of this selected alternative are described below. This summary reflects the features listed in table 6-1 and table K1-1.

a. Nodes

1. Command facilities. The operational commander ashore will have a centralized command center and an alternate designated C^2 center afloat, and an available airborne command post. At-sea commanders and unit platforms will have suitable tailored command centers. The shore complex will be self-sustaining for 120 days, afloat platforms for 60 days. Prespecified commands noncollocated with the central shore site and designated at-sea commanders subordinate to the OTC have the requisite authority for the automatic assumption of command. There will be provisions for system-wide notification of command assumption. The aforementioned command centers will have redundant terminations via a unified DoD packet switched network to the NCA, to primary ocean surveillance and intelligence nodes, and to Task Force circuits; and designated commands

will have authority/capability of injecting critical messages in the MEECN. Alternate command centers will maintain essential elements of information contained in the central shore site via periodic update. The at-sea commanders also will update alternate at-sea command centers with such information.

b. Nodal Subsystems

1. Standards. Internal time, location, and frequency standards are provided for periodic updating of positional information of at-sea forces operating in synchronous nets so that they are able to locate themselves in both space and time. Positional information is provided in terms of true (lat/long) and relative to meet the accuracy requirements of C^3 including the accuracy requirements for short-/long-range aircraft inertial update and guidance of OTH weaponry. The provision of these standards including laser gyro for missiles will enhance the coordination of multimissile, multiplatform employment via command control nets. This alternative also provides for distribution nets on large platforms which reduce the cost of providing time, frequency, location, and vectors to electronic functions distributed throughout the platform.

2. Links. Transmission links that will be needed in the NC^3N are those which exploit the diverse spectra of electromagnetic, optical, and acoustic media for meeting global connectivity requirements. Commercial and non-Navy assets also will be used in crisis situations. The attributes of required links include extensive system-wide automation and integrity. Media connectivity will include vlf thru vhf, uhf and shf satellite mix for ship-shore-ship, wireline/microwave for shore interconnections, and elf/vlf and optical Satcom capability for submarines, major flags, and carriers. Hf also will be required, particularly for use as a backup link. The provision of techniques and procedures will be incorporated to ensure that the NC^3N will be able to operate gracefully in various degraded states to the MEECN level. Preplanned capability to access selected private satellite systems and selected survivable non-Navy sites, such as NORAD and SAC, for onward relay/interconnection to the NCA via WWMCCS will be provided. All ship-shore-ship terminations are established automatically with direct access to DCS. New high-speed efficient tactical data links,

synchronized on the basis of internal nodal time standards, are provided among all combatants and underway replenishment (UNREP) groups and shore commands. The addition of scatter mode optical links may be possible. Procedures and techniques are included to provide automatic reconfiguration of networks to accommodate command structure changes. System I includes the provision for LPI/AJ with automatic recognition of mode shifts for all major combatants and UNREP groups and for major shore commanders. This alternative also provides for direct access to certain remote sensor systems by designated at-sea commanders. All links of this alternative are highly coordinated in time, frequency, and space domains, and are reactive to selected preset thresholds. Such links will optimize platform and task force EMC and will provide multiplatform automated passive triangulation on emitter sources. They also provide bistatic sensing and automated hand-over from one sensor to another for target following and for confusing enemy ARM targeting.

c. Information Processing Subsystem

1. Data processors. This alternative provides medium-scale/microcomputer networks tailored to the requirements of each command within the NC^3N. It suggests extensive use of LSI and electro-optic coupling techniques. The indicated processors have semiautomatic/automatic on-line self-diagnostic and fault isolation and processor semiautomatic reconfiguration capabilities. They are capable, along with their attendant storage devices, of incremental expansion. They will be oriented to operate in a multiprocessing mode and may have access to other large- or medium-scale computers geographically distributed within the NC^3N. System-wide data processor compatibility is emphasized. Also, hardware standardization among ashore and afloat systems is a stated goal of this alternative.

2. Systems programs. System I provides for rigorous system access security, system continuity, communications interface and network control, and powerful on-line nodal man/machine interactions; and through the provision of a standardized, highly flexible set of software modules provides a very capable internodal computer-to-computer interface. Other system program attributes include:

- Extensive provision for dynamic allocation of ADP resources

- Provision for semiautomatic/automatic on-line fault detection, isolation, memory protection, and processor reconfiguration in event of malfunction
- Segregated EXEC for stand-alone CPUs and distributed redundant EXECs for multiprocessor configurations
- Modular software for ease of replacement, changing, debugging, and incremental expansion
- Standardized high-level languages for ease of programming, including debugging
- Control of multiple hardware and software accessibility checks
- Adaptable, clock synchronous automatic network protocols

3. Data base

(a) Reporting structure. This alternative advocates complete standardization of the reporting structure and includes the following system-wide attributes:

- Standardized reports by format, type, and content with menus resident in each node's data base
- System recognition of alternate authority leading to immediate required reconfiguration of reporting structure
- Standardization of reporting requirements in terms of periodicity and addresses
- Maximization of reporting by exception
- System recognition of media changes necessitated by EMCON

(b) Data base structure. This alternative provides for a geographically centralized data base at each command center with selected redundant essential elements of information from various other command facilities; and the capability of nodes to access data bases of other nodes in the NC^3N. Other attributes of this alternative include:

- Complete standardization of formatting for all data bases
- Employment of data compression techniques
- The provision of optimum serial/parallel file structure which is reconfigurable with situational changes

4. Application program. This alternative includes extensive hardware incorporation of commonly used programs supported by modular programs, each with sufficient capacity to meet operational requirements. Functional capabilities include:

- Source/destination and handling requirements categorization
- Formatting/conversion of data
- Multisensor correlation
- Situation monitor, action recall and replay, and threshold comparison
- Alert generation/intranodal routine
- Time/movement projection
- Readiness/logistics status prediction
- Bayesian updating and hypothesis testing
- Sensors/weapons effectiveness prediction
- Communications degradation prediction
- Warfare interaction/outcome prediction
- Casualty/damage prediction
- Event scheduling
- Force/resource allocation
- Report generation
- I/O processing

5. Procedures. System I advocates the provision of well-defined manual responsibilities for synergistic man/machine interaction in operating situations ranging from mission planning to tactical response, supported by extensive computer-generated checklists and prompting aids. Manual functions include:

- Organization and pattern recognition of unstructured information
- Quantification of initial preference values, risk attitudes, and probability parameters; automated Bayesian updating of probabilities and judgmental updating of remainder
- Translation of force characteristics into capabilities and conceptualization of COAs

- Entry of and evaluation of suitability, feasibility, and acceptability criteria; system assumes primary role in warfare simulation
- Initiation and interaction with force assignment model
- Interactive generation of orders and reports

In the course of NC^3N system design, team processing procedures for both nodal and internode operation should be well-defined.

d. Man/Machine Information Couplers

This alternative advances the requirement for system-wide standardized hardware suites to enhance intra/internodal display/transfer of information, while meeting physical access security requirements. Man/machine information features include the provision of:

Interactive graphics analysis terminals

Multicolor LED or plasma panel display augmented by high-resolution digital TV monitors

Operator/computer selectable microfiche

Data entry access via voice coder/responder and multifunction man-packable keyboard modules, light pen or joystick, and OCR

High-speed facsimile and other hard-copy display and visual/auditory alarms

8.0 R&D INITIATIVES FOR NC^3N

8.1 Introduction

a. Objective

The objective of this section is to structure and describe an R&D program for command control. This program is derived from statements of the present architecture, the architecture expected to exist in 1980, and the architectural objective for post-1985 command control (C^2).

b. Scope

Any commander or any military decision maker for that matter must concern himself with all data and information which may affect, or be used in the process of, C^2. The commander must therefore concern himself with the gathering, processing (eg, decision making), and dissemination of all such data and information. This is the essence of C^2.

The best way to describe and characterize this data and information handling problem and the associated system design is by means of a network representation (ref 9).

Hence, one is eventually led to the implementation of C^2 in terms of a global command control and communications (C^3) network.

The R&D program for C^2 described here is one to ensure the eventual construction of a global C^3 network to support C^2 in the gathering, processing, and dissemination of all C^2 information.

8.2 Methodology

The R&D program for C^2 is described in terms of a structured set of closely interrelated projects. The structure is described in section 3, figure 3-2, in terms of a four-dimensional matrix. The dimensions are:

- The application (ie, what operational capabilities is the project relevant to?)
- The system attribute (ie, what system characteristics ("ility") is the project relevant to?)

[9] "Networks constitute one of the most significant classes of application problems in management science. Yet the extent of their pervasiveness has only recently come to be realized. A wide array of problems in production, distribution, financial planning, project selection, facilities location, resource management and budget allocation – to mention only a few – fall naturally in the network domain." Glover, F, and Klingman, D, *Network Application in Industry and Government*, Texas University Center for Cybernetic Studies, Research Report 247, September 1975

- The system function (ie, what is done in the node?)
- The system component (ie, what parts of the system are to be constructed?)

Table 8-3 in section 8.3 lists the projects and relates them to three of the four dimensions for defining project relevancy. Figure 8-1 illustrates the relevancy structure and shows how an R&D project may satisfy only a small portion of each axis.

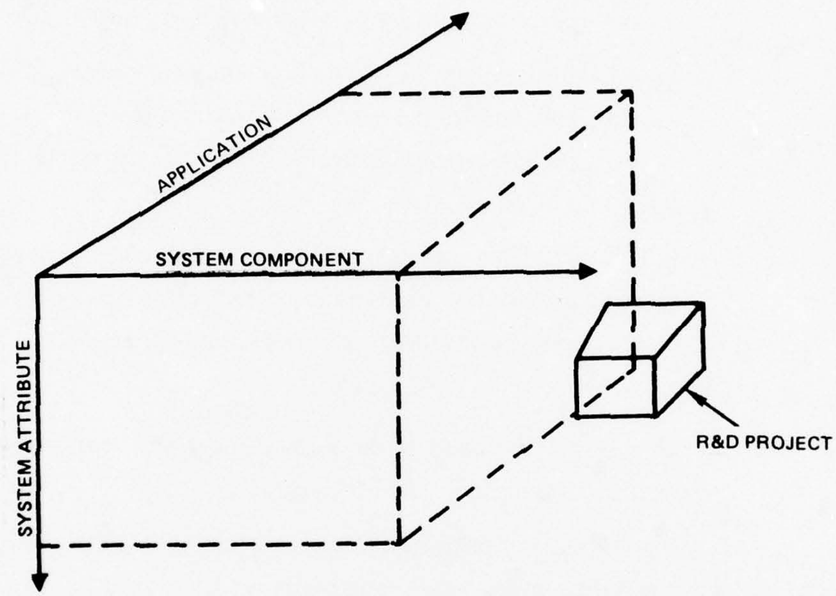


Figure 8-1. The three dimensions for defining relevancy of C^3 projects.

8.2.1 Definitions of Terms

a. Applications

Applications are the use of the system to gather, process, and disseminate data and information for the following seven purposes:

1. Target location. This includes location of any geographic feature, location of enemy, neutral, or friendly platforms, as well as location of own platform. It also includes determining motion vectors.
2. Communications. This application of the system is for transferring information or data among cooperating nodes in a network either man to man, man to machine, or machine to machine.
3. Control. This application refers to direct cause-and-effect (automatic or reflexive) mechanisms (such as weapons control).

4. Countermeasures. This application refers to those uses of the system which prevent the enemy from effectively applying his system for locating, communicating, controlling, measuring and predicting the environment, or identifying or gathering intelligence.

5. Measuring and predicting the environment. This includes meteorology, oceanology, electromagnetic phenomena, and geologic phenomena.

6. Target identification. This includes identifying targets by classes (eg, air, ship, sub; or enemy, friendly, neutral) but also with specific capabilities (eg, speed, weapons, electronics) as well as a possible unique identifier (eg, a ship name).

7. Intelligence. This application of the system is a manipulation of available data and information to derive indicators, estimates, or predictions of future enemy capabilities or possible courses of action.

b. Attributes

1. Economy. The ability of the system to perform at an acceptable level with low cost or loss (low life-cycle cost).

2. Survivability. The capability of the system to survive and function in a specified nuclear war environment.

3. Flexibility/adaptability. The ability of the system to be reconfigured to suit changes in the system environment or to overcome a failure or casualty within the system. This includes the ability to evolve over time.

4. Invulnerability. The ability of the system to operate in the presence of intentional or unintentional electromagnetic interference and to resist enemy attempts to derive information by monitoring and intercept.

5. Interoperability. The ability to support cooperative activity among DoD components, with allied forces on common missions and tasks, and with other groups both civil and private involved in common undertakings.

6. Quality. The accuracy with which the system reproduces an input (fidelity) or a representation of reality such as unambiguous, accurate presentation of a target location.

7. Availability. The portion of time that a system is capable of performing in a specified way and within a specified time (in C^2 terminology, in operational time).

8. Responsiveness. Ability of the system to perform specified functions in operational time.

9. Connectivity. The ranges and directions in space over which C^2 functions can be performed (eg, ranges and directions over which a target can be detected or a communication path can be or is established).

10. Usability. Ease with which human users can interact with the system.

11. Capacity. For a link the volume of data that can be transferred per unit time. The volume of data that can be stored. The complexity and number of processes that can be undertaken in a given period of time.

c. System Elements

(See section 6, this volume; and appendix C, volume 4.)

d. System Functions

(See section 6, this volume; and appendix C, volume 4.)

8.2.2 Methodology for Project Evaluation and Selection

Because of time and budget constraints a methodology is required to maximize the marginal benefit to marginal cost ratio of R&D dollars.

Therefore, in selecting projects, the first ordering is according to the importance of C^3 system attributes as follows:

Economy
Survivability
Flexibility
Invulnerability
Interoperability
Quality
Availability
Responsiveness
Connectivity
Usability
Capacity

NOTE: The selection must not be on the basis of a suboptimization but must relate to the effect on the Navy, or at least on global C^3 capability.

Table 8-1 gives a composite ordering related to subsystems and system function. The table is similar to the listing in table 6-1.

An ordering by system application is not proposed, as such an ordering would be time- and situation-dependent.

TABLE 8-1. ESSENTIAL C^3 NETWORK DESIGN FEATURES.

Provided in Sequence:

I. Standards

1. Central kernel on every platform: time, frequency, location, motion vector, crypto, unique address

II. Links

1. Clock start crypto, all bits covered throughout NC^3N including weapons guidance and surveillance networks
2. Joint service standard adaptabie rf signal formats
3. Multimedia connectivity for $P = 0.99$ of successful message delivery

III. Information Processing Subsystem

1. Automated unblocked orderwire capacity for every node
2. Synchronous DAMA operation of high-duty-cycle nets governed by priority
3. Front-end processing to provide common network transaction formats, access procedures, error control, and switching for global interoperability of US forces, and:
4. Distributed processing nets and microprocessor, microcomputer, smart terminal architecture addressing subsystems in following order:
   (a) Provide processors and system programs which will support evolving application programs and data bases
   (b) Define and design the common data base structures needed for C^2
   (c) Define and provide the standard procedural and application program bases for man-machine interaction and for C^2 function execution and addressing functions in following order: (a) information input, (b) situation assessment, (c) report and directive generation, (d) decision and direction

IV. Man-Machine Coupling Devices

1. Processor aided operational-time group view devices
2. Processor aided individual, interactive information entry and retrieval devices

8.3 Listing of New R&D Initiatives

The projects listed in table 8-2 are required to achieve the post-1985 architecture described in section 7.2.2. In many cases, similar work is already in progress (such as EO processing). Such work needs to be reexamined, however, to ensure that it is properly focused.

The listing in table 8-2 has been organized to group projects under six groups and to show related currently programmed R&D work. This is to indicate the focus of each project, even though there may be significant work to be done in one or more other areas.

Projects which have Navy-wide or multiplatform application or impact were emphasized while projects which have platform-specific application were generally avoided. Such platform-specific projects are thought to be under the purview of the platform sponsor within the guidelines and framework of an overall Navy C^3 architecture.

Table 8-3 lists again the projects given in table 8-2 in a matrix that shows ("X" marks) the subsystems which are primarily affected and (check marks) the subsystems which are affected secondarily. An "X" also indicates the system applications that the project is aimed toward and the system attributes the project is primarily intended to improve.

Interrelationships among projects and subprojects are indicated in each column. The columns indicating the affected subsystem are especially important from the point of view of integrated design and complementary effort. For example, a designer or project manager working on a given link can see at a glance where there are a large number of other projects on link designs which he must be at least familiar with. He can also see (reading across the row) that his effort will include at least some aspects of standards, information processing subsystems, or man-machine couplers. A glance at these columns will show other projects which may be closely related to his own.

The descriptions of the listed R&D initiatives are given in appendix L.

TABLE 8-2. LISTING OF R&D PROJECTS AND RELATED CURRENT PROJECTS.

Project Name	Related Current Project Elements (PE) and Project Titles	
Project Group I – Command Facilities		
A. Optimum Mix and Distribution of Command Facilities	63717N	TFCC
	63520N	SSN Integrated Communications Center
	63582N	ASMC Combat Systems Integration
B. Optimized Command Center Arrangements	64518N	CIC Conversion Escort C & C
	64711N	FCC
C. Integrated System Control and Management Facility	64711N	ASWCCCS
	63228N	CY TSC
	63519N	TFCC
D. Empirical Studies on Command Center Man/Machine, Man/Man Interaction Emphasizing Team Processes	63519N	Tactical Data Systems

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TABLE 8-2 (Continued)

Project Name	PE	Related Current Project Elements (PE) and Project Titles
Project Group II -- Link Designs		
A. AJ/LPI Signal & Link Design		
a. For Radar Against Bistatic Intercept		
b. For Sonar Against Bistatic Intercept		
c. For hf Including Programmable Modem	62721N	
d. Mystic Link (L_x Band) and C Band	25604N	Mystic Link
e. Acoustic		
f. Adaptive Antennas		
B. New Links		
a. Blue-Green Laser for Satcom, Target Detection	63520N	SAOCS
b. IR For Target Detection	63201N	ORICS
c. Satellite Radar	63202N	*Fiber Optics*
d. Passive Millimeter Wave Target Detection	62721N	
e. Fiber Optics		
f. Off-Board EM Decoys		
g. Bistatic Detection Techniques		
h. Acoustic Links		
i. Small Ship/AC/SHF Satcom		
j. hf		
k. uhf		
C. EMC Design		
D. Predicting Link Performance in Operational Time		
a. Antenna Radiation Distribution	63451N	Solrad Hi
b. Propagation Prediction & Information Distribution	62721N	Catalog of Ocean Sounds
c. Electromagnetic Interference Projections		
d. Link Quality & Availability Based on i, ii, iii.		
e. Environmental Noise (em & acoustic)		

TABLE 8-2. (Continued)

Project Name	PE	Related Current Project Elements (PE) and Project Titles
Project Group III – Standards		
A. Standards (Frequency, Time, Location, Crypto)	6320 N	Laser Gyro
a. Laser Gyro for Missiles	63518N	Electrically Suspended Gyro
b. Distributed Netting for Standards	63518N	Doppler Sonar Velocity Log
c. Time, Frequency for Manpack	64765N	Navstar GPS
	63401N	Navstar GPS

TABLE 8-2 (Continued)

Project Name	Related Current Project Elements (PE) and Project Titles	
Project Group IV – Information Processing Subsystem		
A. Data Processors		
a. Distributed Processing and Data Base Configurations		
b. Mini and Micro Computers		
c. CCD and Magnetic Bubble Memory Devices		
d. Fiber Optic Bundles and Couplers		
e. EO Processing		
B. System Programs		
a. Distributed Processing System Programs		
b. Scheduling and Networking Algorithms		
(1) DAMA Netting for: hf, uhf, Satellites, Manpack Radio	25604N 63519N	Mystic Link Tactical Data Systems
(2) Statistically Orthogonal Nets (L_X & C Band AJ Nets)	63366N 63306N	Adv Surface Missile Guidance ASM Guidance Technology
(3) Multiplatform/Multimissile Control Netting for OTH Targets	63766N 64517N	MTACCS Adv Tact CCCP (Joint Service Netting & GAMO)
(4) Netting for Distributed Function Architecture Using Fiber-Optic & Cable	63717N 63306N	Command Support Concept Dev Task Force AAW Coord
(5) Bistatic Multisensor Netting		
(6) Automatic Orderwire for Global Networks		
(7) Joint Service Coord of Network Developments for Interoperability (access protocols, error control, data format, routing)		
c. Multilevel Security		
d. Trend Analysis		
e. Status and System Operation Statistics		
f. Data Maintenance		
g. On-Line Display Support		
h. Computer Language Assist		
i. Statistical Learning by the Computer		
j. Deductive Processing		

TABLE 8-2 (Continued)

Project Name	Related Current Project Elements (PE) and Project Titles	
Project Group IV – Information Processing Subsystem (cont)		
C. Data Bases		
a. Reporting Structure	64711N	Composite Reporting System
b. Data Base Structure and Format		
D. Application Programs		
a. Action Recall & Replaying	63711N	Fleet Tac D & E Tac Dev Support
b. Navigation	64765M	TESE
c. Dynamic Assessment & Evaluation	25670N	Ship Tactical Intelligence Support
d. Data Base Management	63206N	Passive Active Radar Identification
e. Gaming	63506N	Ship Acoustic & Torpedo Countermeasures
f. Multisensor Correlation	63515N	Advanced Identification Technology
g. Assessment and Control	63708N	ASW Automatic Detection/Automatic Classification
h. Information Display	63717N	Command Support Concepts Development
i. Information Input/Output	64219N	S-3A Avionics (Acoustic Data Proc, ECM)
	64261N	Machine Assisted Det & Class (Acoustic)
	28010N	(Peripherals)
	35896N	(Distr Nets)
	63202N	Adv A/C Elec Systems
	63519N	AADC
	61153N	Theory/Techniques of Info Proc
	61153N	Info Proc Sys Development
	62721N	Info Storage & Retrieval
	62721N	Info Transformation
E. Procedures		
a. Organization/Pattern Recognition of Unstructured Information		
b. Quantification Parameters		
c. Translation of Force Characteristics		
d. Tentative COAs		
e. Suitability/Acceptability/Feasibility Criteria		
f. Force Assignment Model		
g. Generation of Orders and Reports		
h. System Access Procedures		

TABLE 8-2 (Continued)

Project Name	PE	Related Current Project Elements (PE) and Project Titles
Project Group V – Man/Machine Couplers		
A. Tactical Display Suite		
a. Shipboard/Shore Display Requirements	63202N	Advanced Integrated Modular Instrumentation System (AIMIS)
b. Subsystem Access/Control Requirements		
c. Multicolor Flat Panel GVD	63585N	Surface Ship Bridge Control System
d. Standardized Interactive Graphics Terminals	64223N	Visual Target Acquisition, ID & WC for F-14
e. Display Processor/Multiplexer	64518N	Data Display
f. Semiautomatic Data Entry/Access	64766M	Tactical Combat Operational System (Amphibious)
	62721N	Displays

TABLE 8-3. PROJECT RELEVANCE.

X = PRIMARY, √ = SECONDARY.

System Relevance	Node/ Subsystem					System Applications							System Attributes										
Project Number / Abbreviated Project Title	Facilities	Links	Standards	IP	MMC	Target Location	Communications	Control	Countermeasures	Environmental Measurement & Prediction	Target Identification	Intelligence	Economy	Survivability	Flexibility	Invulnerability	Interoperability	Quality	Availability	Responsiveness	Connectivity	Usability	Capacity
1. Command Facilities																							
A. Optimum Mix Dist of Facilities	X	√		√		X	X	X	X	X	X	X	X	X	X	X	X			X	X		
B. Optimized Cmd Cont Arr	X				√	X	X	X	X	X	X	X	X				X	X				X	
C. Integrated Sys Mgt & Cont Facility	X					X	√	X	X	X	X	X	X		X	X			X	X		X	X
D. Empirical Studies – Cmd Center				X	X	X	X	X				X	X		X		X	X		X	X	X	
Man-Machine, Man-Man Interaction	√																						
2. Link Design																							
A. AJ/LPI Signal & Link Design																							
a. Radar Against Bistat Intercept		X	√	√					X				X	X	X	X					X		
b. Sonar Against Bistat Intercept		X	√	√					X				X	X	X	X					X		
c. hf and Programmable Modem		X	√	√			X		X				X	X	X	X					X		
d. Mystic Link (L_X Band) & C Band		X	√	√			X		X				X	X	X	X					X		
e. Acoustic Comm		X	√	√			X		X				X	X	X	X					X		
f. Adaptive Antennas		X	√	√			X		X				X	X	X	X					X		
B. New Links																							
a. Bl-Gr Laser for Satcom, Target Det		X				X	X		X	X			X	X	X	X			X		X		X
b. IR for Target Det		X				X			X		X	X		X		X							X
c. Satellite Radar		X				X					X	X						X	X		X		
d. Passive mm wave Target Det		X				X					X					X		X	X		X		
e. Fiber Optics		X					X	X					X	X	X	X		X	X		X		
f. Off-Board EM Decoys		X						X						X	X	X							
g. Bistatic Det Tech		X				X				X			X	X	X	X			X		X		
h. Acoustic Links		X					X														X		
i. Small Ship A/C shf Satcom		X	√				X						X	X	X			X	X		X		X.
j. hf		X	√				X						X	X	X			X	X		X		X
k. uhf		X	√				X							X	X			X	X		X		X

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e. Fiber Optics		X					X	X					X	X	X	X		X	X		X		
f. Off-Board EM Decoys		X						X						X	X	X							
g. Bistatic Det Tech		X				X				X			X	X	X	X			X		X		
h. Acoustic Links		X					X														X		
i. Small Ship A/C shf Satcom		X	✓				X						X	X	X			X	X		X		X
j. hf		X	✓				X						X	X	X			X	X		X		X
k. uhf		X	✓				X							X	X			X	X		X		X
C. EMC, EMV, EMP Design		X												X				X	X				
D. Predict Link Perf in Op Time																							
a. Antenna Radiation Dist		✓		X	X	X	X	X	X				X	X	X	X		X	X	X	X		
b. Propagation Pred & Info Dist		✓		X	X	X	X	X	X	X			X	X	X	X		X	X	X	X		
c. EM Interference Proj		✓		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		
d. Link Qual & Avail		✓		X	X	X	X	X	X				X	X	X	X		X	X	X	X		
e. Environ Noise (em & acoustic)		✓		X	X	X	X	X	X				X	X	X	X		X	X	X	X		
3. Standards																							
a. Laser Gyro		✓	X			X	X	X	X				X		X	X		X	X	X	X	X	
b. Distr Net for Standards		✓	X			X	X	X	X	X	X	X	X		X	X	X		X				X
c. Time, Freq for Manpack		✓	X				X		X							X	X	X	X	X	X		
4. Information Processing																							
A. Data Processors																							
a. Dist Proc & Data Base Config	✓			X	X		✓	X					X		X	X	X	X	X	✓	X		✓
b. Mini & Micro Computers	X	✓		X	X		✓	X					X		X	X	X	X	✓	✓	X		X
c. CCD & Bubble Memory Devices				X			✓						✓					X	✓	X			X
d. Fiber Optic Bundles & Couplers				X			X	✓					X		X	X	X	X	X	✓	X		X
e. EO Processing				X			✓	X					X			X		X		✓			X
B. System Programs																							
a. Dist Proc Sys Programs	✓			X	✓		X	X					X			X	X	X	X	X	X		
b. Sched & Networking Algorithms																							
(1) DAMA Netting for hf, uhf,	✓			X			X	X	X				X	X	X	X	X	X	X	X	X	X	X
satellites, manpack																							
(2) Statist Ortho Nets	✓			X			X	X	X				X	X	X	X	X	X	X	X	X	X	X
(L_X & C Band AJ)																							
(3) Multiplatform/Missile	✓			X		X	X	X	X				X	X	X	X	X	X	X	X	X	X	X
Cont Nets for OTH Targets																							
(4) Fiberoptic Nets for Dist Arch	✓			X			X	X	X				X	X	X	X	X	X	X	X	X	X	X
(5) Bistatic Multisensor Nets	✓			X		X			X		X		X	X	X	X	X	X	X	X	X	X	X
(6) Auto Orderwire for Global Nets	✓			X			X	X	X				X	X	X	X	X	X	X	X	X	X	X
(7) Joint Service Coord Dev	✓			X			X	X	X				X	X	X	X	X	X	X	X	X	X	X
Interop (Access Protocols,																							
Enor Cont)																							
c. MLS	✓	✓		X	✓			X					X			X							
d. Trend Analysis				X	✓			X									X	X	X	X	X		
e. Oper Status	✓	✓		X				X										X	X				X
f. Data, Maintenance				X				X							X			X		X			
g. Display Support	✓			X	X			X							X		X	X		X		X	
h. Computer Lang Assist				X	✓			X							X		X	X		X			
i. Statistical Learning				X				X				X			X			X					
j. Deductive Processing				X	✓			X	X		X	X			X		X	X		X	X	X	
C. Data Bases																							
a. Report of Structure	X	✓		X			X	X					X		X		X	X		X	X	X	X
b. Data Base Structure	✓			X				X					X	X	X		X	X	X	X	X	X	X
D. Application Programs																							
a. Recall & Playback				X	X	X		X	✓	✓	✓	✓	X		X		X	X		X		X	
b. Navigation				X		X		X	✓	✓								X			X		
c. Dynamic Assess & Eval				X		X		X	✓	✓	X	X	X		X			X		X		X	
d. Data Base Mgt	✓			X	✓			X							X		X	X				X	
e. Gaming				X	✓	X	✓	✓	✓	X	✓	X	X		X			X		X		X	
f. Multisensor Corr		✓		X		X	✓	X	✓	✓	X	✓						X		X		X	
g. Assessment & Control	✓			X		X	✓	X	✓	✓	✓	✓			X		X	X	X	X			
h. Information Display				X	X	X	X	X	✓	✓	✓	✓			X		X	X		X		X	
i. Information I/O		✓		X			X	X							X		X			X	X	X	
E. Procedures																							
[illegible]				X	✓	X			X	X		X						X		X		X	

Cont Nets for OTH Targets																							
(4) Fiberoptic Nets for Dist Arch	✓			X			X	X	X				X	X	X	X	X	X	X	X	X	X	X
(5) Bistatic Multisensor Nets	✓			X		X			X		X		X	X	X	X	X	X	X	X	X	X	X
(6) Auto Orderwire for Global Nets	✓			X			X	X	X				X	X	X	X	X	X	X	X	X	X	X
(7) Joint Service Coord Dev	✓			X			X	X	X				X	X	X	X	X	X	X	X	X	X	X
Interop (Access Protocols,																							
Enor Cont)																							
c. MLS	✓	✓		X	✓			X					X			X							
d. Trend Analysis				X	✓			X									X	X	X	X	X		
e. Oper Status	✓	✓		X				X										X	X				X
f. Data, Maintenance				X				X							X			X		X			
g. Display Support	✓			X	X			X							X		X	X		X		X	
h. Computer Lang Assist				X	✓			X							X		X	X		X			
i. Statistical Learning				X				X				X			X			X					
j. Deductive Processing				X	✓			X	X		X	X			X		X	X		X	X	X	
C. Data Bases																							
a. Report of Structure	X	✓		X			X	X					X		X		X	X		X	X	X	X
b. Data Base Structure	✓			X				X					X	X	X		X	X	X	X	X	X	X
D. Application Programs																							
a. Recall & Playback				X	X	X		X	✓	✓	✓	✓	X		X		X	X		X		X	
b. Navigation				X		X		X	✓	✓								X			X		
c. Dynamic Assess & Eval				X		X		X	✓	✓	X	X	X		X			X		X		X	
d. Data Base Mgt	✓			X	✓			X							X		X	X				X	
e. Gaming				X	✓	X	✓	✓	✓	X	✓	X	X		X			X		X		X	
f. Multisensor Corr		✓		X		X	✓	X	✓	✓	X	✓						X		X		X	
g. Assessment & Control	✓			X		X	✓	X	✓	✓	✓	✓			X		X	X	X	X			
h. Information Display				X	X	X	X	X	✓	✓	✓	✓			X		X	X		X		X	
i. Information I/O		✓		X			X	X							X		X			X	X	X	
E. Procedures																							
a. Org/Pattern Recognition				X	✓	X			X	X		X						X		X		X	
b. Quant Parameters				X	✓	X		X		X	X	X						X		X		X	
c. Trans of Force Char				X	✓			X		X		X						X		X		X	
d. Tentative COAs				X	✓	X	X	X	X	X	X	X						X		X		X	
e. COAs Criteria				X	✓	X	X	X	X	X	X	X						X		X		X	
f. Force Assignment Model				X	✓	X	X	X	X	X	X	X						X		X		X	
g. Gen of Orders/Rprt				X	✓		X	X										X		X		X	
h. System Access Proc				X	✓		X	X								X	X	X		X		X	
5. Man/Machine Couplers																							
A. Tactical Display Suite																							
a. Ship/Shore Display Req					X			X					X				X						
b. Access/Control Req				✓	X			X									X	X		X		X	
c. Multicolor GVD					X	X		X	X	X	X	X						X		X		X	X
d. Stdr Inter Graph Term				✓	X	X	X	X	X	X	X	X					X	X		X	X	X	
e. Display Processor				✓	X			X											X			X	X
f. Semiauto Data Entry/Access				✓	X			X									X	X		X		X	

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9.0 MANAGEMENT ISSUES

Previous sections of this document have described or defined:

How requirements should be stated

How the C^3 system should be broken into its component elements

The essential structure and principles and design features of the Navy C^3 architecture

A logical progression from mission and environmental analysis through C^3 system design and validation

Needed C^3 initiatives

The needed C^3 initiatives defined in section 5.0 are managerial, not technological. Some of the needed initiatives relate to changes of managerial structures to correct deficiencies that are of the kind which caused the CIACT* (report to CNO July 1972) to admonish the Navy to organize properly.

Some of the structural problems show symptoms in terms of the way funding is categorized. For example, the existing funding and management structure inappropriately divides C^3 into communications and command control components. (A better way of partitioning C^3 is given in this document.) In the civilian marketplace this division is making itself felt in terms of a major legal upheaval to try to define where regulated communications systems end and ADP systems begin.

The current S & TOs and ORs for C^3 reflect a lack of appreciation of the difference between funding line items (inputs) and mission capabilities (output), and assume a very simple relationship between them. User needs (desired mission capabilities) are usually matched independently one to one with fund allocations. It would be better to have a combined statement of all user needs and to partition the funds to correlate with subsystems. The subsystems would be identified in the system engineering process of partitioning a common user system aimed at satisfying the integrated set of all user needs.

Another major issue is that of managerial innovation. Experience has shown that organizations responsible for the current and near-term functions cannot also be responsible for innovative thinking, since the urgent tends to suppress the important.

Basically, the following are needed:

- A group within OPNAV committed to providing thoughtful, challenging, and innovative inputs to CNO for his Navy Strategic Concept (NSC) and his Policy and Planning Guide (PPG).

*CNO Industrial Advisory Committee on Telecommunications

- Commitment within OPNAV to innovative C^3 architecture which responds explicitly to the NSC and PPG and which is the catalyst for a Navy-wide consensus on C^3. This architecture must provide the universal umbrella under which all Navy electronic system interfaces and interoperability standards are developed, and must guide all designs for information gathering, processing, and dissemination.
- An acceptable overall Navy consensus on C^3 which provides a framework within which OPNAV platform and program sponsors and user communities can control their development programs and resources.
- A NAVMAT organization committed to a modular, standardized common user electronic system development which is capable of supplying the needs of all platform designers from a standardized modular shopping list.
- Restructuring of the funding categories to conform to the evolving architectural consensus so that program sponsors are not constrained by mismatches between evolving systems and outmoded administrative structures.

An initiative was made by the Navy to solve the problem in C^3 by founding the C^3 Architecture Group, OP-943. This has been, to this date, the main Navy response to the CIACT admonition to organize properly. This group was almost immediately given additional responsibility for a large variety of near-term problems with the result that there is danger that insufficient resources will be available for innovative long-term architectural planning.

There is a continuing need for the Navy to set aside a very small amount of resources to support in-house, long-term, challenging, and innovative planning for the Navy C^3 future. Such an innovative group must be protected from the need to respond to near-term fire drills, which, through their demand for manpower, will cause the group to lose its integrity and focus through growth of staff and need for constant short-view compromises.

The Navy has recognized that its ability to carry out its mission is inseparable from an integrated and comprehensive C^3 concept and system. This means the Navy must avoid fragmented management authority and organizational biases which create an environment of compromise before the fact.

There is a need to define desired C^2 capability independently of ongoing programs – and prior to the design of new C^3 systems. Further, components of the C^3 system must be broken out according to a commonly accepted structure. Developments which require parallel effort in two or more components must be managed in concert. This means balanced development effort within the context of a comprehensive OPNAV architecture and NAVMAT development plan.

The Navy has taken an innovative and forward-looking point of view, in terms of planning. out to the year 2000 and beyond, about its future in naval platforms, and has instituted long-term developments while sacrificing current capability (at some recognized risk) by retiring obsolete platforms.

The capabilities proposed for C^3 in this document will require developments which because of fiscal and technological constraints, will take until the year 2000 to implement completely in the fleet. This will require perseverance in maintaining the long-term view of an innovative C^3 development concurrent with advanced platform concepts.

The Navy's prime guidance from the office of CNO should consist of: a Navy Strategic Concept (NSC), the CNO Policy and Planning Guide (PPG), and a Navy Command Control and Communication Architecture (NC^3A). The NC^3A must define the command concepts and structure in response to the PPG and NSC (including concepts for forming, organizing, and controlling forces to carry out Navy missions). It must also define the performance and numbers of the various platforms and support organizations which must be called upon to participate in the defined command structures. Finally, a NAVMAT C^3 Development Plan in response to the C^3 architecture is required.

These documents would be the Navy's top-level guidance for all electronic system sponsors and development agents.

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AUG 76 R L GOODBODY, V J MONTELEON
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San Diego, California 92152

1 July 1977

LITERATURE CHANGE

NELC Technical Document 504
NAVY COMMAND CONTROL AND COMMUNICATIONS SYSTEM DESIGN PRINCIPLES AND CONCEPTS, Volumes I through VIII, 15 August 1976

1. In block 10 of DD Form 1473, change numbers to:
   65866N, X0740, X0740 (NELC Q221)

2. On cover, under date, add:
   Changed 1 July 1977